File Ref.No.Ac.C1/Faculty of Science/2021

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

(Abstract)

Faculty of Science - Revised Course Structure and Syllabus - M.Sc Chemistry, 5 Year Integrated M.Sc Chemistry and 5 Year Integrated M.Sc Biological Science - Approved - Orders issued.

ACADEMIC C SECTION

No.CUSAT/AC(C).C1/3928/2021 Dated,KOCHI-22,04.11.2021

Read:-Item No.I (e) of the minutes of the meeting of the Academic Council held on 28.07.2021.

ORDER

The Academic Council at its meeting held on 28.07.2021, vide minutes item read above, considered the minutes of the combined meeting of Board of Studies in Chemistry and Board of Studies in Chemical and Biological Sciences along with the recommendation of the Standing Committee and resolved to approve the revised structure and syllabus of the three programmes, viz. M.Sc Chemistry, 5 Year Integrated M.Sc Chemistry and 5 Year Integrated M.Sc Biological Science as in Appendices 1, 2 and 3 respectively..

Orders are issued accordingly.

Dr. Meera V *
Registrar

To:

1. Dr.K Girish Kumar, Dean of Faculty of Science & Professor, Department of Applied Chemistry, CUSAT, Kochi-22
2. Dr.K.Sreekumar, Chairman, Board of Studies in Chemical and Biological Science & Professor, Department of Applied Chemistry, CUSAT, Kochi-22.
3. The Head, Department of Biotechnology, CUSAT, Kochi-22.
4. The Head, Department of Chemistry, CUSAT, Kochi-22.
5. PS to V.C/PS to PVC/PA to Registrar
6. The Controller of Examinations/ The Director, Academic Admissions/ JR (Exams)/ DR (Exams/Academic Admissions)
7. Exam B/D/E/P/Y sections/ Academic A/C sections
8. Day File/Stock File/File Copy.

* This is a computer generated document. Hence no signature is required.

Appendix -1

Department of Applied Chemistry

Cochin University of Science and Technology

M.Sc. Chemistry Syllabus

2021-22

Programme Objective

The M. Sc. course in Chemistry aims to build human resources in the area of Chemical Science and create trained competent manpower which can take challenges in teaching and research.

Programme Outcomes

On successful completion of M. Sc. Chemistry programme, students will be able to

P.O.1: acquire systematic and coherent understanding of the fundamental concepts.

P.O.2: demonstrate comprehensive knowledge and understanding of both theoretical and experimental/applied chemistry in various fields.

P.O.3: design and perform the chemical synthesis and characterise the products.

P.O.4: design and execute experimental routines for detection and quantification of chemical entities.

P.O.5: analyse the kinetics and energetics of chemical processes and infer the mechanism.

P.O.6: demonstrate the basic principles of instrumental methods of analysis.

P.O.7: operate advanced instruments and related soft-wares to execute in-depth analysis of chemical problems.

P.O.8: acquire core competency in the subject.

P.O.9: acquire skills for future employment in academia and industry.

P.O.10: demonstrate knowledge relevant to the regional, national and international development needs.

SEMESTER: 1

Semester Credit: 21(Core: 16; Elective: 5) Cumulative Credit:21

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 2101	Inorganic Chemistry -I (Concepts and Developments)	Core	3	3-1-0	50	50	100
CHE 2102	Organic Chemistry-I (Reactivity and Mechanisms)	Core	4	4-1-0	50	50	100
CHE 2103	Theoretical Chemistry-I (Quantum Chemistry)	Core	3	3-1-0	50	50	100
CHE 2104	Theoretical Chemistry-II (Group Theory and Spectroscopy)	Core	4	4-1-0	50	50	100
CHE 2105	Advanced Chemical Synthesis and Separation Lab	Core	2	0-0-6	100	-	100
CHE 2106	Open Ended Lab-I	Core[c]	-	0-0-6	-	-	-
CHE 2107	Equilibrium Thermodynamics	Elective	3	3-1-0	50	50	100
CHE 2108	Environmental Chemistry	Elective	2	2-1-0	50	50	100
CHE 2109	Advanced Stereochemistry	Elective	2	2-1-0	50	50	100
CHE 2110	Professional and Career Development in Chemistry	Audit [a]	-	2-0-0	-	-	-

SEMESTER: 2

Semester Credit: 22 (Core: 16; Elective: 6) Cumulative Credit:43

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 2201	Inorganic Chemistry-II (Chemistry of d- and f- Block Elements)	Core	3	3-1-0	50	50	100
CHE 2202	Organic Chemistry -II (Reactions, Reagents and Synthesis)	Core	4	4-1-0	50	50	100
CHE 2203	Organic Chemistry -III (Spectroscopy of Organic Compounds)	Core	2	2-1-0	50	50	100
CHE 2204	Physical Chemistry-I (Statistical and Nonequilibrium Thermodynamics)	Core	3	3-1-0	50	50	100
CHE 2205	Theoretical Chemistry-III (Chemical Bonding and Computational Chemistry)	Core	2	1-1-3	50	50	100
CHE 2206	Advanced Physical Chemistry Lab	Core	2	0-0-6	100	-	100
CHE 2207	Open Ended Lab-II	Core[c]	-	0-0-6	-	-	-
CHE 2208	Bioanalytical Chemistry	Elective	2	2-1-0	50	50	100
CHE 2209	Polymer Chemistry	Elective	2	2-1-0	50	50	100
CHE 2210	Advanced Photochemistry	Elective	2	2-1-0	50	50	100
CHE 2211	Theory of Orbital Interactions in Chemistry	Elective	2	1-1-3	50	50	100
CHE 2212	Chemical Crystallography	Elective[b]	4	4-1-0	50	50	100

SEMESTER: 3

Semester Credit: 21(Core: 17; Elective: 4) Cumulative Credit:64

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 2301	Analytical Chemistry (Advanced Analytical Techniques and Instrumental Methods)	Core	4	4-1-0	50	50	100
CHE 2302	Inorganic Chemistry -III (Organometallic and Bioinorganic Chemistry)	Core	3	3-1-0	50	50	100
CHE 2303	Organic Chemistry-IV (Chemistry of Natural Products)	Core	3	3-1-0	50	50	100
CHE 2304	Physical Chemistry-II (Chemical Kinetics, Reaction Dynamics, Catalysis and Surface Chemistry)	Core	3	3-1-0	50	50	100
CHE 2305	Physical Chemistry-III (Advanced Electrochemistry)	Core	2	2-1-0	50	50	100
CHE 2306	Open Ended Lab-III	Core	2	0-0-6	100	-	100
CHE 2307	Interdepartmental Elective	Elective	4	4-1-0	50	50	100
CHE 2308	Oleochemicals, Nutraceuticals, Surfactant Technology	Elective	2	2-1-0	50	50	100
CHE 2309	Materials Chemistry	Elective	2	2-1-0	50	50	100
CHE 2310	Bonds and Bands in Solids	Elective[b]	2	2-1-0	50	50	100

SEMESTER: 4

Semester Credit: 16(Core: 16; Elective: 0) Cumulative Credit:80

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 2401	Project Dissertation and Viva Voce	Core	16	-	-	300	300

Interdepartmental Elective Offered by the Department							
CHE 2311	Molecular Modelling in Chemistry	Elective	4	4-1-0	50	50	100
CHE 2312	Spectroscopic Techniques	Elective	4	4-1-0	50	50	100

a-Value Added Course

b-MOOC Course

c-Evaluation in third semester

L-T-P ≡ Lecture-Tutorial-Practical Hours

CE ≡ Continuous Evaluation; ESE ≡ End Semester Evaluation

CORE

CHE 2101

INORGANIC CHEMSITRY-I

(CONCEPTS AND DEVELOPMENTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Identify the structure-activity relationship of simple molecules based on their qualitative molecular orbitals.	Analyse
C.O. 2: Predict the stability and topology of different polyhedral boranes and related compounds.	Analyse
C.O. 3: Assess the strength of various acids and bases and their reactivity.	Analyse
C.O. 4: Explain behavior of different non-aqueous solvent systems towards different reactions.	Apply
C.O. 5: Interpret the structure and properties of compounds of sulfur, nitrogen, phosphorous and group 14 elements.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					
C.O. 5	x	x			x					

UNIT – 1 **(10 hrs)**

Qualitative molecular orbital theory, symmetry of molecular orbitals, MOs for homo and heteronuclear diatomic molecules, H_2 to F_2, HF, CO, NO, BeH_2, CO_2,

H_2O, BH_3, NH_3, B_2H_6, $B_3N_3H_6$, S_3N_3, $N_3P_3Cl_6$, Si_2H_2. Importance of frontier molecular orbitals, Shape, energy and reactivity of molecules.

UNIT – 2 **(10 hrs)**

Electronic structure and allotropes of boron, boron halides, boron heterocycles, borazine Structure and bonding in polyhedral boranes and carboranes, styx notation; electron count in polyhedral boranes; Wade's rule; topological approach to boron hydride structure. Importance of icosahedral framework of boron atoms in boron chemistry. Closo, nido and arachno structures. Synthesis of polyhedral boranes; electron counting in polycondensed polyhedral boranes, mno rule.
Carboranes, metallocarboranes; Boron halides, boron heterocycles, borazine.

UNIT – 3 **(10 hrs)**

Relative strength of acids, Pauling rules, Lux-Flood concept, Lewis concept, Generalized acid-base concept, Measurement of acid base strength, Lewis acid – base interactions, steric and solvation effects, acid–base anomalies, Pearson's HSAB concept, acid-base strength and hardness and softness, Symbiosis, theoretical basis of hardness and softness, electronegativity and hardness.

UNIT – 4 **(8 hrs)**

Chemistry in non-aqueous solvents reactions in NH_3, liquid SO_2, solvent character, reactions in SO_2, acetic acid, solvent character, reactions in H_2SO_4 and some other solvents. Molten salts, Green solvent: supercritical CO_2, Ionic liquids
and deep eutectic solvents.

UNIT – 5 **(10 hrs)**

Sulphur-Nitrogen compounds: Tetrasulphur tetranitride, disulphur dinitride and polythiazyl. SxNy compounds. S-N cations and anions. Sulphur-phosphorus compounds: Molecular sulphides such as P_4S_3, P_4S_7, P_4S_9 and P_4S_{10}. Phosphorus-nitrogen compounds: Phosphazenes and poly phosphazenes. Transition metal dichalcogenides, MoS_2. Structure, bonding and reactivity of 2D and 3D Carbon, Silicon and Germanium materials. Carbon nitrides, fullerenes, carbon nanotubes

(CNT's) and graphenes.

Recommended Text Books:

1. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed., Pearson, 2014.
2. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of Structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
3. F. A. Cotton, G. Wilkinson, C. A, Murillo, M. Bochmann, Advanced Inorganic Chemistry, 6th ed., Wiley-Interscience: New York, 1999.
4. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3rd ed., ELBS, 1999.
5. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd ed., Wiley, 1994.
6. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd ed., Butterworth-Heinemann, 1997.
7. C.E. Housecroft, A.G. Sharpe, Inorganic Chemistry, 5th ed., Pearson, 2018.
8. E. Wiberg, A.F. Holleman, N. Wiberg, Inorganic Chemistry, Academic Press,2001.
9. A. V. Kolobov, J. Tominaga, Two-Dimensional Transition Metal Dichalcogenides, Springer, 2016.
10. Yu-Chuan Lin, Properties of Synthetic Two-dimensional Materials and Heterostructures, Springer, 2018.
11. Changzheng Wu, Xiaojun Wu, et al, Inorganic Two-dimensional Nanomaterials: Fundamental Understanding, Characterization and Energy Applications, RSC, 2017
12. D.R. MacFarlane, Mega Kar, J.M. Pringle, Fundamentals of ionic liquids, Wiley-VCH, 2017.
13. Yizhak Marcus, Deep Eutectic Solvents, Springer, 2019.
14. J.M. DeSimone and W. Tumas, Green Chemistry Using Liquid and Supercritical Carbon dioxide, D.U.P, 2003.
15. F. M. Kerton , R. Marriott , et al., Alternative Solvents For Green Chemistry, 2nd ed., RSC, 2013.

CORE

CHE 2102

ORGANIC CHEMISTRY -I

(REACTIVITY AND MECHANISMS)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Review different bonding models with emphasis on understanding three dimensional structures of molecules.	Analyse
C.O.2: Study Qualitative Molecular Orbital Theory and group orbital concepts to sketch MO's of common organic structures, functional groups etc.	Evaluate
C.O.3: Apply the concepts of Frontier orbital theory in the study of ionic, radical and pericyclic reactions.	Analyse
C.O.4: Interpret structure and stability of reactive intermediates.	Evaluate
C.O.5: Apply methods and techniques to study mechanisms of organic reactions.	Apply
C.O.6: Predict the reactivity of an organic compound from its structure and based on the reaction conditions.	Evaluate
C.O.7: Propose a reasonable mechanism for a given organic reaction.	Evaluate
C.O.8: Predict the products in a particular reaction considering the stereochemical aspect.	Evaluate
C.O.9: Illustrate the mechanistic pathway of different rearrangement reactions and identify the products.	Analyse
C.O.10: Identify the mechanism and the product in a given reaction under photochemical condition.	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		
C.O.5	x	x						x		
C.O.6	x	x			x			x		
C.O.7	x	x			x			x		
C.O.8	x	x			x			x		
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		

UNIT – 1 **(10 hrs)**

Study of Structure and Models of bonding: VB and MO models of bonding, Structure and Stability of Reactive intermediates: Carbocations, Carbanions, Carbenes, Nitrenes, and Radicals. Bonding Weaker than Covalent Bonds. Solvent and solution properties, solvent scales. Acid – Base properties in non-aqueous systems, acidity scales, Applications of Molecular Orbital Theory in Understanding reactions and Mechanisms. Qualitative MO theory. Group orbitals. Frontier Orbitals, Substituent effects on frontier orbitals, HSAB concept, Nucleophiles and Electrophiles, Perturbation theory of reactivity. Application of Frontier Orbital theory in studying ionic and radical reactions, Ambident electrophiles, α-effect.

UNIT – 2 **(10 hrs)**

The study of reactions and the methods of studying reaction mechanisms.

Classification of reactions according to IUPAC conventions. Reaction mechanism: guidelines on Pushing of electrons. Reactive intermediates: Formation, stability and general reactivity. Methods of determining reaction mechanisms (kinetic and non kinetic methods): The Hammond postulate,
reactivity vs selectivity principle, the Curtin-Hammett principle, microscopic

reversibility, kinetic vs thermodynamic control. Isotope effects: Primary,secondary and Equilibrium isotope effects, Tunneling effects, solvent isotope effects and heavy atom Isotope effects.

Linear free energy relationships: Hammett and Taft parameters, Solvent effects (Grunwald-Winstein plots and Schleyer adaptation), nucleophilicity and nucleofugality. Isokinetic and Isoequilibrium temperature, Enthalpy – entropy compensation. Experimental techniques to determine reaction mechanisms: identification of intermediates by trapping and competition experiments, cross - over experiments, isotope scrambling, radical clocks and traps, matrix isolation

UNIT – 3 **(14 hrs)**

Substitutions on Aliphatic carbon – saturated and unsaturated systems – Mechanism of nucleophilic substitution – SN2, SN1 – ion pairs, SET, Neighbouring group participation – non classical carbocations, SNi, Tetrahedral mechanism. Electrophilic substitution – SE2, SEi, SE1. Free radical substitution. Reactivity – Effect of substrate structure, nature of reagents, solvents and stereochemistry on the outcome of these reactions. Ambident nucleophiles and substrates. Typical reactions involving substitution.

Substitutions on aromatic carbon: Mechanism of electrophilic, nucleophilic and free radical substitutions – orientation and reactivity. Typical reactions involving aromatic substitution.

UNIT – 4 **(16 hrs)**

Mechanisms of polar addition – electrophilic, nucleophilic and free radical addition. Nonpolar additions (excluding pericyclic reactions) - Reactivity and orientation. Eliminations - E2, E1 and E1CB mechanisms, reactivity and orientation. Pyrolytic syn eliminations, α - eliminations, elimination vs. substitution. Typical reactions involving addition and elimination.

Rearrangements involving electron deficient carbon and nitrogen. Mechanism of the following rearrangements: Wagner-Meerwein, Pinacol, Demyanov, dienone-phenol, Favorskii, Wolff, Hofmann, Curtius, Lossen, Schmidt, Beckmann, benzidine, and Hofmann-Loffler, Fries, Baeyer-Villiger rearrangements. Fritsch-Buttenberg-Wiechell rearrangement, Corey-Fuchs reaction, Seyferth-Gilbert homologation, Grubbs catalysts and olefinmetathesis.

UNIT – 5 **(14 hrs)**

Pericyclic reactions: study of the principle of conservation of orbital symmetry: Orbital symmetry diagrams for cycloaddition and electrocyclic reactions. Aromatic Transition State Theory and The Generalized Woodward – Hoffmann rule applied to cycloaddtions, Electrocyclic reactions, Sigmatropic rearrangements and Chelotropic reactions.

Pericyclic Reactions in Organic Synthesis: Stereochemistry and Regiochemistry of Cycloaddtions. Substituent and medium effects, Secondary Orbital Interactions in [4+2] cycloadditions, Intramolecular Diels–Alder reactions. Stereochemistry of Electrocyclic Reactions and Sigmatropic rearrangements. Cope rearrangement, Claisen rearrangement and ene-reaction.

1,3-dipolar cycloaddition reactions, Photochromism and thermochromism, Pericyclic reactions in Organic synthesis – case studies.

Photochemistry: Unimolecular and bimolecular processes in the excited states, mechanism of important photochemical reactions, Paterno-Buchi reaction, Norrish Type I and Type II fragmentation, di-pimethane rearrangement, Barton reaction, photochemistry of olefins, arenes, cyclohexadienones; photoreduction and photo-oxygenation..

Recommended Text Books:

1. J. March, Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 7^{th} ed., Wiley, 2013.

2. T. H. Lowry, K. S. Richardson, Mechanism and Theory in Organic Chemistry, 3rd ed., Benjamin-Cummings Publishing Company, 1997.
3. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
4. E. V. Anslyn, D. A. Dougherty, Modern Physical Organic Chemistry. University Science Books, 2006.
5. F. A. Carroll, Perspectives on structure and mechanism in organic chemistry, Wiley, 2011.
6. N. S. Issacs, Physical Organic Chemistry, 2nd Edition, Prentice Hall, 1995.
7. A. Pross, Theoretical and Physical Principles of Organic Chemistry, 1st ed., Wiley, 1995.
8. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
9. I. Flemming: Molecular orbitals and organic chemical reactions, student ed., Wiley, 2009.
10. J. McMurry, Organic Chemistry, 5th ed., Brooks/Cole, 2000.
11. R. Bruckner, Advanced organic chemistry: Reaction Mechanisms. Academic Press, 2001.
12. P. Sykes, Guidebook to Mechanism in Organic Chemistry, 6th ed., Prentice Hall, 1986.
13. N. J. Turro, Modern Molecular Photochemistry, University Science Books, 1996.
14. N. J. Turro, J. C. Scaiano, V. Ramamurthy, Modern Molecular Photochemistry of Organic Molecules, 1st ed., University Science Books, 2010.

CORE

CHE 2103

THEORETICAL CHEMISTRY-I
(QUANTUM CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Account for the basic principles and concepts of quantum mechanics.	Analyse
C.O.2: Apply the postulates of quantum mechanics to simple systems of chemical interest, such as the particle-in-a-box, harmonic oscillator, rigid rotor, and hydrogenic atoms.	Apply
C.O.3: Derive the variational principle, use it to calculate properties for simple systems of chemical interest.	Analyse
C.O.4: Use perturbation theory to calculate properties for simple systems of chemical interest.	Analyse
C.O.5: Define and explain the Hartree-Fock self-consistent field method.	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		
C.O. 5	x	x						x		

Semester 1

UNIT – 1 **(10 hrs)**

Wave-particle duality, uncertainty principle, postulates of quantum mechanics, Schrödinger equation, Time dependent and time independent Schrodinger wave equation. Its application on some model systems viz., free particle, particle in one, two and three-dimensional box (rectangular and cubical), separation of variables, concept of degeneracy, introduction to quantum mechanical tunneling.

UNIT – 2 **(10 hrs)**

Vibrational motion, Harmonic oscillator, Method of power series, Hermite equation and Hermite Polynomials, Recursion formula, wave function and energy. Rigid rotator, Wave function in spherical polar coordinates, Planar rotator, phi equation, theta equation and solutions Lagendre equation and Lagendre polynomials, Spherical harmonics, Angular momentum operator L^2 and L_z, Space quantization.

UNIT – 3 **(10 hrs)**

H atom, separation into three equations and solutions, Laguerre equation and Laguerre polynomials wave equation and energy of H like systems, quantum numbers and their importance, Radial wave function and radial distribution functions, angular wave function, Shapes of s, p, d and f atomic orbitals.

Postulate of electron spin-orbital and spin functions. Zeeman effect.

UNIT – 4 **(12 hrs)**

Many electron atoms. Approximate methods in quantum mechanics: The variation theorem, linear variation principle and perturbation theory (first order and non-degenerate), application of variation method and perturbation theory to the Helium atom, antisymmetry, Pauli exclusion principle, Slatter determinantal wave functions. Electron spin

UNIT – 5 **(6 hrs)**

Hartree-Fock Self Consistent Field method, The Coulomb and Exchange Operators, The Fock Operator, Koopmans' theorem, Brillouin's theorem, The Roothaan Equations, Slater's treatment of complex atoms, Slater orbitals. Pauli principle, Slater determinant and wave function.

Recommended Text Books:

1. D. A. McQuarrie, Quantum Chemistry, 3rd ed., Univ. Sci. Books, Mill Valley, California, 1983.
2. I. N. Levine, Quantum Chemistry, 6th ed., Pearson Education, London, 2008.
3. P. W. Atkins, R.S Friedman, Molecular Quantum Mechanics, 5th ed., OUP, Oxford, 2012.
4. J. P. Lowe, Quantum Chemistry 3rd ed., Academic Press, New York, 2008.
5. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Book ed., Mc.Graw-Hill, New York, 1982.
6. P.W. Atkins, Physical Chemistry, 8th ed., Wiley, New York, 2006.
7. R. K. Prasad, Quantum Chemistry, 3rd ed., New Age International, 2006.
8. D. J. Griffiths, Introduction to Quantum Mechanics, 2nd ed., 2004.
9. J. J. Sakurai, Modern Quantum Mechanics, 2nd ed., 2010.

CORE

CHE 2104

THEORETICAL CHEMSITRY-II

(GROUP THEORY AND SPECTROSCOPY)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Analyze the symmetry of any given molecule and assign the point group	Analyze
C.O.2: Apply the principles of symmetry and group theory in structure, bonding and spectral characteristics of molecules	Apply
C.O.3: Explain the factors affecting the intensity and broadening of lines in spectra and methods to enhance the sensitivity	Understand
C.O.4: Explain the principles of rotational, vibrational, Raman, electronic, fluorescence and NMR spectroscopy	Understand
C.O.5: Solve problems based on rotational, vibrational, Raman electronic, fluorescence and NMR spectroscopy	Apply
C.O.6: Apply various theoretical aspects to various spectroscopic techniques for prediction of different spectroscopic observations	Analyze

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x	x	x		x	
C.O.4	x	x			x	x	x		x	
C.O. 5	x	x			x	x	x		x	
C.O. 6	x	x			x	x	x		x	

UNIT – 1 **(18 hrs)**

Matrix representation of symmetry operations, similarity transformation and classes, Symmetry classification of molecules into point groups (Schoenflies symbol)- Application of symmetry to predict polar and chiral compounds. Reducible and Irreducible representations - Great Orthogonality theorem and its consequences (statement only, proof not needed), Character tables, Reduction formula, construction of character tables for point groups with order ≤6-, Interpretation of character tables. Wave functions as bases for irreducible representations, Direct product.

UNIT – 2 **(12 hrs)**

Application of symmetry to predict polar and chiral compounds. Application of Group theory to Hybridization of atomic orbitals: Construction of hybrid orbitals for AB_3(planar), $AB_4(T_d)$, $AB_5(D_{3h})$ and $AB_6(O_h)$ type of molecules.

Application of group theory to Molecular Orbital Theory: LCAO and Huckel approximations. Symmetry adapted linear combinations, Projection operators, Application of projection operators to pi-bonding in ethylene, cyclopropenyl systems, benzene and naphthalene. Application of projection operators to sigma bonding in ethylene and $PtCl_4^{2-}$. Molecular orbitals for tetrahedral and octahedral molecules.

UNIT – 3 **(12 hrs)**

Spectroscopy and its importance in chemistry. Link between spectroscopy and quantum chemistry, Energy levels in molecules, Born-Oppenheimer approximation,

Absorption and emission of radiation, Intensity and width of spectral lines, Beer lambert's law, Integrated absorption coefficient, Line width – natural line broadening, Doppler broadening, minimisation of line broadening, Induced and spontaneous transitions, correlation to the Einstein coefficients of absorption and emission, Basis of selection rules Fermi golden rule, lasers.

UNIT – 4 **(12 hrs)**

Rotational spectroscopy: Rotation of rigid bodies, moment of inertia, linear molecules, spherical, symmetric and asymmetric tops, Schrödinger equation of a rigid rotator and brief discussion of its results, Quantization of rotational energy levels, selection rules, rotational spectra and line intensities, structure determination from rotational constants, isotopic effects.

Vibrational Motion: Schrödinger equation of a linear harmonic oscillator and brief discussion of its results, concept of zero-point energy. Quantization of vibrational energy levels. Selection rules, IR spectra of diatomic molecules. Structural information derived from vibrational spectra, dissociation energies, vibration-rotation transitions in diatomics, harmonic oscillator, anharmonicity, centrifugal distortion, Vibration of polyatomic molecules, normal modes, combination, difference and hot bands, Fermi Resonance, Group frequencies. Effect of hydrogen bonding (inter- and intramolecular) on vibrational frequencies.

Raman spectroscopy: Light scattering and Raman effect, classical and quantum models for scattering, Stokes and anti-Stokes lines; their intensity difference, polarizability, selection rules, group theoretical treatment of vibrations, Effect of nuclear spin, Vibrational Raman spectra, rule of mutual exclusion for centrosymmetric molecules, polarized and depolarized Raman lines, resonance Raman scattering.

Applications of Group theory for molecular vibration, symmetry of group vibrations. Selection rules and applications to IR and Raman spectra.

UNIT – 5 **(10 hrs)**

Electronic Spectroscopy of molecules: Molecular orbitals and states, term symbols, selection rules, vibrational and rotational structures, Free Electron model, its application to electronic spectra of polyenes. Frank-Condon principle, electronic transitions, Beer Lambert's Law, dissociation and predissociation, photoelectron spectroscopy, dissociation and predissociation, calculation of heat of dissociation, Birge Sponer method, electronic spectroscopy of polyatomic molecules

Singlet and triplet states, Jablonski diagram, fluorescence and phosphorescence, Solvent and environmental effects, Fluorescence quenching, energy transfer and electron transfer, time domain lifetime measurements.

NMR: Expression for Hamiltonian/Energy - Zeeman interaction, torque exerted by a magnetic field on spins, equation, its solution and the physical picture of precession. Thermal equilibrium, Relaxation, chemical shift, shielding and deshielding, Karplus relationships, Bloch equations, the rotating frame, pulsed experiments, NOE, double irradiation, selective decoupling, double resonance, Polarisation transfer, Two-dimensional NMR, Solid state NMR, NQR, MRI

Recommended Text Books:

1. F. A. Cotton, Chemical Applications of Group theory, Wiley Eastern, Singapore, 2nd ed., 1992.

2. V. Ramakrishnan, M. S. Gopinathan, Group theory in Chemistry, Vishal Pub. New Delhi, 1996.

3. Alan Vincent, Molecular Symmetry and Group Theory: A Programmed Introduction to Chemical Applications, 2nd ed., Wiley, 2013.

4. Robert L. Carter, Molecular Symmetry and Group Theory, Wiley, 2009.

5. G. M. Barrow, Introduction to Molecular Spectroscopy, McGraw Hill, New York, 1962.

6. C. N. Banwell, Fundamentals of Molecular Spectroscopy, 4th ed., Tata McGraw Hill, 1996.

7. A. E. Derome, Modern NMR Techniques for Chemical Research, Pergamon Press, 1987.

8. D. H. Williams, I. Flemming, Spectroscopic Methods in Organic Chemistry, 4th ed., McGraw-Hill, 1985.

9. H. Gunther, NMR Spectroscopy, 2nd ed., John Wiley, 2005.

10. N. B. Colthup, L. H. Daly, S. E. Wiberley, Introduction to Infrared and Raman Spectroscopy, 3rd ed., 1982.

11. R. A. Alberty, Physical Chemistry 8th ed., Wiley, New York, 1994.

12. P. W. Atkins, Physical Chemistry 8th ed., W. H. Freeman, New York, 2006.

13. I. N. Levine, Molecular Spectroscopy, John Wiley & Sons.

14. J. M. Hollas, Modern Spectroscopy, John Wiley & Sons.

15. P. F. Bernath, Spectra of Atoms and Molecules, III Edn, Oxford University Press.

16. J. L. McHale Molecular Spectroscopy, Pearson Education.

17. W. W. Parson, Modern Optical Spectroscopy, Springer-Verlag.

18. Jack D. Graybeal, Molecular Spectroscopy, Mc Graw Hill International Editions

19. M.H. Levitt, Spin Dynamics, II edn.Wiley

20. James Keeler, Understanding NMR spectroscopy, II edn. Wiley

21. Joseph R. Lakowicz, Principles of Fluorescene Spectroscopy, 3rd Ed., Plenum Press, 2010.

CORE

CHE 2105

ADVANCED CHEMICAL SYNTHESIS AND SEPARATION LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Acquire knowledge on safe laboratory practices of handling laboratory glassware, equipment and chemical reagents.	Knowledge
C.O.2: Plan and perform synthetic procedures, chromatographic separation and purification of organic compounds.	Understand
C.O.3: Separate organic compounds from the organic binary mixture and identify the functional group(s) present.	Analysis
C.O.4: Use software to Draw the structures and schemes of organic molecules and reactions.	Apply
C.O.5: Use Chemical Abstracts, Scopus, Organic Synthesis collective volumes on web etc. to search, analyse and collect chemical information.	Apply
C.O.6: Identify the cations in a mixture of unknown salts.	Analyse
C.O.7: Estimate the amount of a given metal ion by complexometric and cerimetric reactions.	Analyse
C.O.8: Synthesise metal complexes and characterize them by various physicochemical methods.	Apply
C.O.9: Record and interpret electronic spectrum of different metal complexes.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x		x	x	
C.O.2	x	x	x		x	x		x	x	
C.O.3	x	x		x		x		x	x	
C.O.4	x	x				x	x	x	x	

C.O.5	x	x			x	x		x	x	
C.O.1	x	x						x	x	
C.O.2	x	x		x				x	x	
C.O.3	x	x	x			x		x	x	
C.O.4	x	x				x	x	x	x	

UNIT – 1 **(48 hrs)**

Part I: General methods of separation and purification of Organic compounds such as 1) Solvent extraction 2) Thin layer chromatography and paper chromatography 3) column chromatography

Part II: Separation and identification of the components of organic binary mixtures.

Part III: Preparation of Organic compounds by multistep reactions, purification of products and characterisation using UV-Vis, FTIR and NMR.*

Part IV: Drawing the structures of organic molecules and reaction schemes by Proprietary and open source computer software. Use Chemical Abstracts, Scopus, Organic Synthesis collective volumes on web etc., to search, analyse and collect chemical information.

*Progress of the reactions should be followed by spectroscopic and chromatographic methods (UV-Vis, TLC, GC, HPLC, etc)

UNIT – 2 **(48 hrs)**

Reactions of titanium, vanadium, chromium, manganese, iron, cobalt, nickel and copper ions. Reactions of some less common metal ions (Tl, W, Mo, V, Zr, Th, U). The spot test technique for metal ions. Semimicro qualitative analysis of common and rare cations in a mixture.

Estimation of metal ions by complexometric and cerimetric titrations. Estimation of Mg, Ca, Mn, hardness of water.

Synthesis of inorganic complexes and their characterization by various physicochemical methods, such as IR, UV, Visible, NMR, magnetic susceptibility etc. Selection can be made from the following or any other complexes for which references are available in the literature.

Tris(oxalato)manganese(III)

Tetrapyridinesilver(II)peroxidisulphate

Tris(acetylacetonato) iron(III)

Bis(N,N-diethyldithiocarbamato)nitrosyliron(I)

Optical isomers of tris(ethylenediamine)cobalt(III)chloride

Nitropentamminecobalt(III) chloride

Tri(acetylacetonato)manganese(III)

Tris(thiourea) copper(I) sulphate

Phenyl lithium

Tetraphenyl lead

Ferrocene

Phosphonitrilic chloride

Anhydrous copper(II) nitrate

Interpretation of its electronic spectrum and calculation of Dq values.

Determination of crystal field splitting energy for certain ligands and construction of a part of the spectrochemical series.

Recommended Text Books:

1. A. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Vogel's Textbook of Practical Organic Chemistry, 5th ed., John Wiley, 1989.
2. D. L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Organic laboratory Techniques, 3rd ed., Saunders Golden Sunburst Series.
3. L. W. Harwood, C. J. Moody, Experimental Organic Chemistry-Principles and Practice, Blackwell Science Publications.
4. G. Pass, H. Sutcliffe. Practical Inorganic Chemistry 2nd ed., Chapman & Hill. 1974.
5. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand, 1972.

CORE/LAB

CHE 2106

OPEN ENDED LAB-I

Credit 0

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validating the hypothesis and Submit Research Proposal

ELECTIVE

CHE 2107

EQUILIBRIUM THERMODYNAMICS

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: To predict changes in thermodynamic parameters during a process and predict the spontaneity.	Apply
C.O. 2: Describe the significance of chemical potential in physical and chemical processes	Apply
C.O. 3: Understand thermodynamics of phase transitions and interpret phase diagram of a given system.	Analyse
C.O. 4: Interpret dependence of chemical equilibrium on pressure, temperature and concentration.	Analyse

	Programme Outcomes							
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6	P.O.7	P.O.8
C.O.1	X	X			X			
C.O.2	X	X			X			
C.O.3	X	X			X			
C.O.4	X	X			X			

UNIT – 1 **(8 hrs)**

Language and Mathematics of Thermodynamics.

Recap of first and second law. The Clausius inequality, Free energy functions - Variation with temperature and pressure. Gibbs Helmholtz equation. Relation between thermodynamic functions. Maxwell relations-significance.

Third law of thermodynamics: Nernst Heat Theorem, Calculation of absolute entropy, Unattainability of absolute zero.

UNIT – 2 **(10 hrs)**

Thermodynamic systems of variable composition – Partial molar properties. Chemical Potential, Significance of Chemical potential, Gibbs Duhem Equation and Duhem Margules Equation. Thermodynamics of mixing. Excess functions, Concepts of activity and fugacity, Standard states.

UNIT – 3 **(10 hrs)**

Physical transformation of Pure substances- Stability of a phase, Phase transitions and phase boundaries- Thermodynamic aspects, Ehrenfest Classification of Phase transitions. Phase rule – Application to one component systems- Water, S, CO_2 and He.

UNIT – 4 **(10 hrs)**

Thermodynamics of Binary systems: Binary liquids- Ideal solutions, Raoults law, Henry's Law, Deviations from ideality, Real and Regular solutions, Excess functions, Ideal Dilute Solutions- Colligative Properties- van't Hoff factor.

Liquid-vapour equilibria of binary systems – Vapour pressure-composition diagrams and Temperature composition diagrams. Distillation of binary mixtures –Azeotrope formation.

Liquid-liquid equilibria- Partially miscible and immiscible liquids- CST, Nernst Distribution Law, Partition co-efficient, Principle of Steam distillation.

Solid-liquid Equilibria-Cooling curve, Eutectic system, Deep Eutectic solvents, Application, Compound formation with Congruent and Incongruent melting points. Salt hydrate water systems,

Solid-Vapour Equilibria- CuSO4-water system. Three component systems.

UNIT – 5 **(10 hrs)**

Chemical Equilibria and free energy, Equilibrium Constants, Applications of free energy function to physical and chemical changes- Le Chateliers Principle. Effect of temperature and pressure on chemical equilibrium- van't Hoff reaction isotherm and isochore.

Recommended Text Books:

1. Peter Atkins and Julio de Paula, Physical Chemistry, Oxford University Press, 8th and10th Edn, 2017.
2. D.A McQuarrie, J.D Simon, Molecular Thermodynamics, Viva Student Edn. 2010.
3. I.N Levine, Physical Chemistry, McGraw Hill Indian Edn, 2011.
4. I. M. Klotz & R. M. Rosenberg, Chemical Thermodynamics, Wiley, 7th Edn, 2008.
5. L. K. Nash, Elements of Chemical Thermodynamics, Addison Wesley, 2nd Edn, 2013.
6. F. Daniels and R. A. Alberty, Physical Chemistry, Wiley Publishers, 4th Edn 2004

ELECTIVE

CHE 2108

ENVIRONMENTAL CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Explain various cycles in environment	Understand
C.O. 2: Identify various air, soil and water pollutants andsuggest methods to control air, water and soil pollutions	Apply
C.O. 3: Discuss the various techniques in environmentalanalysis	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X	X								X
C.O.2	X	X								X
C.O.3	X	X								X

UNIT – 1 **(4 hrs)**

Global warming – Ozone hole. Environmental segments – The hydrological cycle – The oxygen cycle – The nitrogen cycle – The sulphur cycle – Composition of atmosphere – Earth's radiation balance – Green house effect.

UNIT – 2 **(6 hrs)**

Air pollution – Primary pollutants, Acid rain – Air quality standards – Sampling – Monitoring – Analysis of CO, nitrogen oxides, sulphur oxides, hydrocarbons and particulate matter – Control of airpollution.

UNIT – 3 **(6 hrs)**

Soil pollution – Inorganic and organic components in soil – Acid – Base and ion exchange reactions in soils – Micro and macro nutrients – Wastes and pollutants in soil.

UNIT – 4 **(10hrs)**

Water pollution – Water pollutants – Eutrophication – Water quality criteria for domestic and industrial uses – Trace elements in water – Determination of quality parameters – Total hardness, TDS, pH, chloride, heavy metals, etc.

Principles of water and waste water treatment – Aerobic and anaerobic treatment – Industrial waste water treatment – Removal of organic and inorganic materials from water and waste water.

UNIT – 5 **(6 hrs)**

Instrumental techniques in environmental analysis – Use of neutron activation analysis – ASV, AAS, GC, HPLC, ion selective electrodes and ion chromatography in environmental chemical analysis.

Recommended Text Books:

1. Environmental Chemistry, Gary W. VanLoon, Stephen J. Duffy, Oxford University Press,2005
2. Principles of Environmental Chemistry, James Girard, Jones & Bartlett Learning,2005
3. Environmental Chemistry, Seventh Edition, Stanley E. Manahan, CRC Press,2010
4. Applications of Environmental Chemistry, Eugene R. Weiner, CRCPress,2010
5. Environmental chemistry, Ian Williams, J. Wiley, 2001
6. The essential guide to environmental chemistry, Georg Schwedt, John Wiley,2010

ELECTIVE

CHE 2109

ADVANCED STEREOCHEMISTRY

Credit 2 **32 hours**

<u>Course Outcome</u> After the completion of the course the student will be able to	**<u>Cognitive level</u>**
C.O.1: Understand the concept of Configuration and conformation of organic compounds	Understand
C.O.2: Apply the concepts of conformation and configuration in organic chemistry.	Apply
C.O.3: Apply the concepts of stereochemistry and conformation chemistry of carbohydrates	Apply
C.O.4: Analyze the effect of molecular conformation in the outcome of a reaction.	Analyze

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x	x	
C.O.2	x	x						x	x	
C.O.3	x	x						x	x	
C.O.4	x	x						x	x	

UNIT – 1 **(4 hrs)**

Geometrical isomerism, origin – structural features including C-C and C-hetero atom double bonds, cyclic systems and other systems exhibiting restricted rotation, different nomenclature including, *cis-tarns, E-Z, syn-anti, endo-exo, in-out*, relative acidity of maleic and fumaric acids.

UNIT – 2 **(6 hrs)**

Optical isomerism, origin of chirality, chiral centres, axes and planes, helicity, enantiotopic and diastereotopic atoms, groups and faces, prochiral centres and faces, allenes, cumulenes, biphenyls, and spirans. Compounds containing chiral atoms other than carbon.

Brief introduction to CD and ORD techniques, octant rule, axial haloketone rule, and sign of Cotton effect

UNIT – 3 **(6 hrs)**

Conformational analysis, Acyclic sp^3–sp^3, sp^3-sp^2 systems, structure and stability of small, medium, and large rings, cyclohexane, substituted cyclohexanes, *A*values, cyclohexenes, decalins, bicyclic systems. Strain, types of strain including *B, F, I,* Pitzer strain, Beyer strain.

UNIT – 4 **(6 hrs)**

Conformation and Stereo-electronic Effects of carbohydrates: *D* and *L* sugars, Chair conformation, Endo/Exo-anomeric effect, Reverse anomeric effect, Glycosidic torsion angles, Hydroxymethyl group conformation. Conformationand stability of aldohexoes, structure and conformation of ribose and deoxyribose.

UNIT – 5 **(10 hrs)**

Reaction Mechanisms and Conformational Effects on Reactivity - Ester Hydrolysis, Alcohol Oxidations, S_N2 Reactions, Elimination Reactions, Epoxidation by Intramolecular Closure of Halohydrins, Epoxide Openings (S_N2), Electrophilic Additions to Olefins, Rearrangement Reactions, Conformationaland Stereoelectronic Effects on Reactivity.

Stereoselective Reactions of cyclic compounds. Reactions on Small Rings. Stereochemical Control in Six Membered Rings. Stereochemistry of Bicyclic Compounds. Reactions with Cyclic Intermediates/Transition states.

Recommended Text Books:

1. March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8^{th} Ed., Wiley, 2020.
2. T H. Lowry and K.S. Richardson: Mechanism and Theory in Organic Chemistry, 3^{rd} Ed., Benjamin-Cummings Publishing Company, 1997.
3. F. A. Carey and R. J. Sundberg: Advanced Organic Chemistry (parts A and B), 5^{th} Ed., Springer, 2010.
4. E. V. Anslyn and D. A. Dougherty: Modern Physical Organic Chemistry. Ist Ed., University Science Books, 2011.
5. F. A. Carroll: Perspectives on structure and mechanism in organic chemistry, 2^{nd} Ed., Wiley, 2011.
6. N. S. Issacs: Physical Organic Chemistry, 2^{nd} Ed., Prentice Hall, 1995.
7. A. Pross: Theoretical and Physical Principles of Organic Chemistry, Ist Ed., Wiley, 1995.
8. J. Clayden, N. Green, S. Warren and P. Wothers: Organic Chemistry, 2^{nd} Ed., Oxford University Press, 2012.
9. P.S.Kalsi: Stereochemistry, Conformation and Mechanism, 9^{th} Ed., New Age Publications, 2017.
10. E. L. Eliel and S. H. Wilen: Stereochemistry in Organic Compounds, 2008, John Wiley.
11. S. H. Pine: Organic Chemistry, 5^{th} Ed., McGraw Hill, 2008.
12. I. Flemming: Molecular orbitals and organic chemical reactions, student edition, 2009, Wiley.
13. J. McMurry, Organic Chemistry, 9^{th} Ed., 2015, Brooks/Cole .
14. D. Nasipuri, Stereochemistry of Organic Compounds: Principles and Applications, 4^{th} Ed., Wiley Eastern Limited, New Delhi, 2012.
15. Eliel, E. L. and Wilen, S. H. Stereochemistry in Organic Compounds, Student Ed., John Wiley, 2008.

AUDIT

CHE 2110

PROFESSIONAL AND CAREER DEVELOPMENT IN CHEMISTRY

Credit 0 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Skills on subject specific pedagogy, soft skills, ICT tools, research proposal writing, finding scholarships and software for chemistry	Create

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1									X	X

UNIT – 1 **(32 hrs)**

Soft Skills – Powerpoint, Word, Exel, Reference management software- Mendeley, Origin, Veusz, Research Proposal Writing – Literature review, Components of proposals, ICT – Google Classroom, Moodle, Class Recording, Teach Infinity, OBS, edmondo, QUIZZ Quiz, Document scanner., Subject specific pedagogy – Molecular model kit, ChemDraw, ChemSketch, Finding International Scholarships- MEXT, DAAD, EURAXESS, J-Rec, Funding through embassy,
Research ethics, research methodology, lab safety.

Recommended Text Books:

7. John M. Swales & Christine B. Feak, Academic Writing for Graduate Students 3rd Edition, Michigan Publishing, 2012
8. Stephen Bailey, Academic Writing, A Handbook for International Student, 5th Edition, Routledge, Taylor & Francis, 2018

CORE

CHE 2201

Inorganic Chemistry – II

(CHEMISTRY OF d- AND f-BLOCK ELEMENTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: describe and explain the structure, bonding and magnetism in metal complexes using crystal field theory.	Analyse
C.O.2: describe various metal-ligand interactions in terms of sigma- and pi-bonding.	Analyse
C.O.3: identify various d-d transitions and interpret the electronic spectra of any given transition metal complex.	Evaluate
C.O.4: interpret the ESR spectra of any given transition metal complex.	Evaluate
C.O.5: explain the stability of metal complexes, their reactivity, and the mechanisms of ligand substitution and redox reactions.	Evaluate
C.O.6: interpret the Mossbauer spectra of iron complexes.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x			x			x		
C.O.3	x	x				x		x		
C.O.4	x	x				x		x		
C.O.5	x	x			x			x		
C.O.6	x	x				x		x		

UNIT – 1 **(6 hrs)**

Crystal-field theory, d-orbital splitting in octahedral, tetrahedral, square planar, trigonal bipyramidal, trigonal planar and linear geometries, crystal field stabilization energy, effect of pairing energy.

Molecular Orbital Theory: construction of molecular orbital diagrams using group theory, qualitative MO diagrams for octahedral, tetrahedral and square planar complexes, effect of π-bonding, experimental evidence for π-bonding, spectrochemical series.

UNIT – 2 **(10 hrs)**

Microstates, Atomic term symbols Free ion terms for dn configuration, Splitting of terms in octahedral and tetrahedral octahedral fields, Correlation diagram for d^2 configuration in octahedral geometry, d-d transitions, Selection rules for electronic transitions.

Orgel diagram – splittings for d^1, d^9, high spin d^4, d^6, splittings for high spin d^2, d^3, d^8 and d^7

Calculation of Dq, B and β

Tanabe Sugano diagrams – splittings for low spin d^n systems

Electronic Spectral interpretation of some coordination compounds

Consequence of Jahn Teller effect on the electronic spectra of coordination compounds

Charge transfer spectra, Electronic spectra of lanthanide and actinide complexes

UNIT – 3 **(6 hrs)**

Magnetism: brief review of different types of magnetic behaviours, spin-orbit coupling, quenching of orbital angular moments in crystal field, spin-only formula, correlation of μ_s and μ_{eff} values, magnetic moments of T terms and A, E terms, temperature independence paramagnetism, magnetic properties of lanthanides and actinides.

UNIT – 4 **(12 hrs)**

Electronic paramagnetic resonance spectroscopy: Electronic Zeeman effect, Zeeman Hamiltonian and EPR transition energy. Presentation of spectra. The effects of electron Zeeman, nuclear Zeeman and electron nuclear hyperfine terms in the Hamiltonian on the energy of the hydrogen atom. Second order effect. Hyperfine splittings in isotropic systems, spin polarization mechanism and McConnell's relations Anisotropy in g-value, EPR of triplet states, zero field splitting, Kramer's rule, survey of EPR spectra of first row transition metal ion complexes.

Mossbauer spectroscopy- Principles and applications to coordination compounds.

UNIT – 5 **(14 hrs)**

Reaction Mechanism: Thermodynamic and kinetic consideration, formation constant and rate constant, inert and labile complexes, factors affecting the stability and lability of complexes.

Ligand substitution in octahedral complexes, mechanism of substitution reactions in octahedral complexes, dissociative, associative and interchange mechanism, energy profile of reactions, acid and base hydrolysis, factors affecting the rate of substitution reactions in octahedral complexes.

Ligand substitution in square planar complexes, mechanism of substitution reactions in square planar complexes, energy profile of reactions, the trans effect and its applications, theories for explaining trans effect, factors affecting the rate of substitution reactions in square planar complexes.

Electron Transfer Reactions: inner sphere and outer sphere mechanism, Marcus theory, photochemical reactions

Recommended Text Books:

1. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5^{th} ed., Pearson, 2014.
2. F. A. Cotton, G. Wilkinson, C. A, Murillo, M. Bochmann Advanced Inorganic Chemistry, 6^{th} ed., Wiley-Interscience: New York, 1999.
3. J.E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of structure and Reactivity, 4^{th} ed., Harper Collin College Publishers, 1993.
4. J. W. Steed, J. L. Atwood, Supramolecular Chemistry, 2^{nd} ed., John Wiley & Sons Ltd., 2009.

5. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3rd ed., ELBS, 1999.
6. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd ed., John Wiley and Sons, 1994.
7. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd ed., BH, 1997.
8. R. S.Drago, Physical Methods for Chemists, 2nd ed., Saunders College Publishing, 1992.
9. C. E. Housecroft, A. G. Sharpe, Inorganic Chemistry, 5th ed., Pearson, 2018.
10. W. L. Jolly, Modern Inorganic Chemistry, 2nd ed., McGraw-Hill, New York, 1991.
11. Leonard K. Nash, Elements of Chemical Thermodynamics, Addison Wesley, 2nd Edn, 2013.

CORE

CHE 2202

ORGANIC CHEMISTRY -II

(REACTIONS, REAGENTS AND SYNTHESIS)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Interpret the differences in reactivity of various reducing and oxidizing agents with mechanistic illustrations.	Apply
C.O.2: Analyse the reagents and conditions for the synthesis of specific target molecules.	Analyse
C.O.3: Describe strategies for the stereospecific/stereo selective organic transformations towards chiral target molecules.	Apply
C.O.4: Construct a synthetic pathway for simple to complex organic molecules by retrosynthetic approach.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x									
C.O.2			x					x		
C.O.3			x					x		
C.O.4			x					x		

UNIT – 1 **(14 hrs)**

Reagents for oxidation and reduction: Chromium reagents, activated DMSO, osmium tetroxide, selenium dioxide, singlet oxygen, peracids, hydrogen peroxide, periodic acid, lead tetraacetate, ozonolysis, Woodward and Prevost hydroxylation, Wacker process, Oppenauer oxidation, Sharpless, Shi and

Jacobsen asymmetric epoxidations. Catalytic hydrogenations (heterogeneous-Palladium/Platinum/Rhodium and Nickel, homogeneous-Wilkinson), metal hydride reduction- $LiAlH_4$, DIBAL-H, Red-Al, $NaBH_4$ and $NaCNBH_3$. Selectrides, trialkylsilanes and trialkyl stannane. Birch reduction, hydrazine and diimide reduction. Meerwein-Ponndorf-Verley reaction, Enzymatic reduction using Baker's yeast..

UNIT – 2 **(12 hrs)**

Synthetic applications of organometallic and organo-nonmetallic reagents: Hydorboration reactions, Sakurai allylation, Gilman's reagent, Ullmann and Glaser coupling reactions. Suzuki coupling, Sonogashira coupling, Heck reaction, Buchwald–Hartwig coupling, Negishi coupling and Stille coupling. Metathesis processes of electrophilic carbene complexes (first- and second-generation Grubbs catalyst), ROMP, Dötz reaction and methylenation of carbonyls.

Reagents such as NBS, DCC, DMAP, DEAD, DDQ. Phase transfer catalysts.

Chemistry of Nucleophilic Heterocyclic Carbenes (NHCs), multicomponent reactions such as Ugi reaction, Passerini reaction, Biginelli reaction. Click reaction.

UNIT – 3 **(12 hrs)**

Chemistry of carbonyl compounds: Reactivity of carbonyl groups in aldehydes, ketones, carboxylic acids, esters, acyl halides and amides. Substitution at carbonyl carbon, mechanisms of ester hydrolysis, substitution at α-carbon, aldol and related reactions. Grignard reaction, Reformatsky reaction, Claisen, Darzen, Dieckmann, Knoevenagel and Stobbe condensations. Perkin, Prins, Mannich, Stork-enamine reactions. Conjugate additions, Michael additions and Robinson annulation. Favorskii reaction, Julia olefination, Peterson olefination.
Reaction with phosphorous and sulfur ylides.

UNIT – 4 **(12 hrs)**

Asymmetric Synthesis: Introduction to asymmetric synthesis, principle, general strategies, chiral pool strategy, chiral auxiliaries, chiral reagents – Binol derivatives of $LiAlH_4$, chiral catalysts – CBS catalyst. Stereospecific and stereoselective synthesis, determination of enantiomeric and diastereomeric excess.

Stereoselective nucleophilic additions to acyclic carbonyl groups-Cram's Rule, Felkin-Ahn Model, Effect of chelation on selectivity.

UNIT – 5 **(14 hrs)**

Synthesis planning and analysis: Convergent, divergent and parallel synthesis. Protecting groups- protection and deprotection of hydroxyl, carboxylic acids, carbonyls in aldehydes and ketones, amines, alkenes and alkynes. Chemo- & regioselective protection and deprotection. Functional group equivalents, reversal of reactivity (Umpolung). Disconnection approach-introduction to retrosynthesis, basic principles, synthons, and synthetic equivalents. Monofunctional and bifunctional disconnection, One group C-X and two group C-X disconnections, one group C-C and two group C-C disconnections. Retrosynthesis of longifoline, Corey lactone, Djerassi - Prelog lactone and D-luciferin.

Recommended Text Books:

1. M. B. Smith, Organic Synthesis, 2nd ed., McGraw-Hill, 2000.
2. M. B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 7th ed., Wiley, 2013.
3. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
4. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
5. P. S. Kalsi, Stereochemistry, Conformation and Mechanism, 9th ed., New Age Publications, 2017.

6. T. Tsuji, Transition Metal Reagents and Catalysts: Innovations in Organic Synthesis, John Wiley & Sons, 2000.
7. S. Warren, Organic Synthesis: The Disconnection Approach, 2nd ed., John Wiley, 2008.
8. E. Robert, Gawley, J. Aube, Principles of Asymmetric Synthesis, 2nd ed., Elsevier, 2012.
9. G. L. D. Krupadanam, Fundamentals of Asymmetric Synthesis, 1st ed., CRC press, 2014.
10. T.W. Greene, P. G. M. Wuts, Protecting Groups in Organic Synthesis, 2nd ed., John Wiley, 1991.
11. H. R. Crabtree, The Organometallic Chemistry of the Transition Metals, 6th ed., John Wiley & Sons, 2014.
12. S. D. Burke, R. L. Danheiser, Handbook of Reagents for Organic Synthesis, John Wiley & Sons, 1999.

CORE

CHE 2203

ORGANIC CHEMISTRY -III

(SPECTROSCOPY OF ORGANIC COMPOUNDS)

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Identify structures of unknown organic compounds using hyphenated techniques and spectral library matching.	Apply
C.O.2: Identify structures of unknown organic compounds based on the data from UV-Vis, IR, Mass Spectrometry ^{1}HNMR and ^{13}CNMR spectroscopy.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x	x	
C.O.2	x	x						x	x	

UNIT – 1 **(6 hrs)**

Study of Mass Spectrometry applied to organic molecular systems

Elemental analysis, empirical formula, molecular formula, Molecular mass, nominal mass, Exact mass, Index of hydrogen deficiency.

The technique of Mass Spectrometry: Molecular ion, ion production methods (EI). Soft ionization methods: FAB, CA, MALDI, PD, Field desorption electrospray ionization, HRMS and formula mass, LC-MS, GC-MS. MS- MS Mass spectra of chemical classes and its correlation with structure: Fragmentation patterns, nitrogen and ring rules, Rule of thirteen, McLafferty rearrangement.

UNIT – 2 **(6 hrs)**

Study of Ultraviolet-Visible Absorption and Emission and Chirooptical Spectroscopy applied to organic molecular systems

Energy levels and selection rules, Woodward-Fieser and Fieser-Kuhn rules, estimation of λmax of substituted aromatic ketones, aldehydes and acids. Spectral correlation with structure: Influence of substituents, conjugation, Intramolecular Charge transfer, Solvent effect

Fluorescence Spectroscopy. Excitation and Emission Spectra. Fluorescence Quantum Yield and Lifetime. Spectral correlation with structure: Influence of substituents, ring size, strain and conjugation, Intramolecular Charge transfer, Intramolecular proton transfer, Solvent effect

Chirooptical Spectroscopy: Introduction and applications of ORD, CD, Octant rule, axial haloketone rule, Cotton effect.

UNIT – 3 **(6 hrs)**

Study of Infrared Spectroscopy applied to organic molecular systems

Fundamental vibrations, overtones, Fermi Resonance, Hot bands, combination bands

Spectral correlation with structure: Characteristic regions of the spectrum. Influence of substituents, ring size, hydrogen bonding, vibrational coupling, hybridization and field effect on frequency.

IR spectra of chemical classes including amino acids and its correlation with structure

UNIT – 4 **(10 hrs)**

Study of NMR spectroscopy applied to organic molecular systems

The NMR instrumentation and Experiment: Magnetic nuclei with special reference to 1H and 13C nuclei. Chemical shift and shielding/deshielding, relaxation processes, chemical and magnetic non-equivalence, local diamagnetic shielding and magnetic anisotropy. Proton and 13C NMR scales, characteristics of 13C as a nucleus.

Spin-spin splitting, AX, AX2, AX3, A2X3, AB, ABC, AMX type coupling, First order and non-first order spectra, Pascal's triangle, coupling constant, mechanism of coupling, Karplus curve, quadrupole broadening and decoupling, diastereomeric protons, virtual coupling, long range coupling effects, NOE, coupling with other nuclei.

Simplification non-first order spectra to first order spectra, shift reagents- mechanism of action, spin decoupling and double resonance, Chemical shifts and homonuclear/heteronuclear couplings, the basis of heteronuclear decoupling.

Polarization transfer. Selective Population Inversion (qualitative description only), DEPT, sensitivity enhancement and spectral editing. 2D NMR and COSY, HMQC, HMBC.

UNIT – 5 **(4 hrs)**

Identification of structures of unknown organic compounds using hyphenated techniques and Spectral library matching.

Identification of structures of unknown organic compounds based on the data from UV-Vis, IR, Mass, 1HNMR and 13CNMR spectroscopy.

Recommended Text Books:

1. D. L. Pavia, G. M. Lampman, G. S. Kriz, J. R. Vyvyan, Introduction to Spectroscopy: A Guide for Students of Organic Chemistry, Indian ed., Brooks/Cole Cengage Learning, 2007.
2. Atta-Ur-Rahman, M. I. Choudhary, Solving Problems with NMR Specroscopy, Academic Press, New York, 1996.
3. L. D. Field; S. Sternhell, J. R. Kalman; Organic Structures from Spectra, 4^{th} ed., Wiley 2008.
4. R. S. Drago, Physical Methods for Chemist, Saunders,1992.

5. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th ed., McGrawHill, 1994.
6. D. F. Taber, Organic Spectroscopic Structure Determination, A Problem Based Learning Approach, Oxford University Press, 2009.
7. R. M. Silverstein, G. C. Bassler, T. C. Morril, Spectroscopic Identification of Organic Compounds, John Wiley, 1991.
8. D. H. Williams, I. Fleming, Spectroscopic Methods in Organic Chemistry, Tata McGraw Hill, 1988.
9. W. Kemp, Organic Spectroscopy, 2nd ed., ELBS-Macmillan, 1987.
10. F. Bernath, Spectra of Atoms and Molecules, 2nd ed., Oxford University Press, 2005.
11. E. B. Wilson, Jr., J. C. Decius, P. C. Cross, Molecular Vibrations: The Theory of Infrared and Raman Spectra, Dover Publications, 1980.
12. A. Weil, J. R. Bolton, Electron Paramagnetic Resonance: Elementary Theoryand Practical Applications, 2nd ed., Wiley Interscience, John Wiley & Sons, Inc.,2007.
13. C. P. Slichter, Principles of Magnetic Resonance, 3rd ed., Springer-Verlag, 1990.
14. H. Gunther, NMR Spectroscopy: Basic Principles, Concepts and Applications in Chemistry, 3rd ed., Wiley- VCH, 2013.
15. Spectral data bases (RIO DB of AIST, for example).

CORE

CHE 2204

PHYSICAL CHEMISTRY- I

(STATISTICAL AND NON-EQUILIBRIUM THERMODYNAMICS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Explain the different types of statistics and calculate the thermodynamic probability of any given thermodynamic system.	Analyse
C.O. 2: Calculate the partition function and thermodynamic properties from spectroscopic data.	Apply
C.O. 3: Apply the principles of statistical thermodynamics to ideal gases, solids and metals.	Apply
C.O. 4: Explain the basics of transport phenomena's viz., Osmosis, biological motors and electro kinetic effects.	Understand
C.O. 5: Derive expression for entropy production for physical and chemical processes	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X	X			X					
C.O.2	X	X			X					
C.O.3	X	X			X					
C.O.4	X	X			X					
C.O.5	X	X			X					

UNIT – 1 **(8 hrs)**

Kinetic Theory of gases, Maxwell Distribution of velocity, Boltzmann distribution, Types of molecular velocities- r.m.s, most probable and mean velocity, Molecular Collisions, Mean free path, Transport properties- Diffusion, effusion, Viscosity, Thermal conductivity.

Thermodynamic probability, microstate and macrostate, entropy andprobability, most probable distribution, residual entropy and its calculation. Ensembles, Maxwell - Boltzmann statistics.

UNIT – 2 **(10 hrs)**

Partition function and its relation to thermodynamic properties, Translational, rotational and Vibrational partition function. Molecular partition function for delocalized systems, calculation of equilibrium constant using partition functions. Heat capacity of gases, Anomalous heat capacity of H_2, Heat capacity of solids: Dulong - Petits law, Einstein's theory and its modification, Debye's theory of heat capacity of solids.

UNIT – 3 **(10 hrs)**

Quantum statistics, Bose - Einstein statistics, Fermi - Dirac statistics, Comparison of Maxell - Boltzman, Bose=- Einstein and Fermi - Dirac Statistics, Dilute Systems. Application of Bose -Einstein Statistics, Gas degeneration, Application to liquid helium, Bose Einstein Condensation. Application of Fermi -Dirac Statistics to electrons in metals, Extreme Gas Degeneration, Electron gas in metals and its contribution to pressure and heat capacity.

UNIT – 4 **(10 hrs)**

Partition function for systems of dependent particles, Configurational integral and configurational partition function. Imperfect gas, van der Waals equation and Virial equation of state, Evaluation of the first virial coefficient. Condensed state, Cluster integrals, Communal entropy.

UNIT – 5 **(10 hrs)**

Linear Non-equilibrium thermodynamics- General theory, Local entropy production, balance equation for concentration. Energy conservation in open systems. Entropy balance equation. Forces and Fluxes, Steady state and local equilibrium conditions. Linear phenomenological laws. Phenomenological coefficient, Systems with heat, matter and electrical transport, Onsager Reciprocal relation, Application to Diffusion -Thermal diffusion, Thermal Osmosis and electrokinetic effects, Soret Coefficient, Seebeck effect.

Recommended Text Books:

1. F.W. Sears, Introductions to Thermodynamics, Kinetic Theory of Gases and Statistical Mechanics, Addision Wesley Pub. Cambridge, 1998.
2. F.C. Andrews, Equilibrium to Statistical Mechanics, John Wiley, New York, 2002.
3. L.K. Nash, Statistical Thermodynamics, Addison Wesley, New York, 1999.
4. P. W. Atkins, J. de Paula, Physical Chemistry 8th ed., 9th edn. Wiley, New York, 2006
5. D. A. McQuarrie, Physical Chemistry- A Molecular Approach, South Asian Edn., 2008.
6. M. Dole, Introduction to Statistical Thermodynamics, Prentice Hall, London, 1997.
7. J. Kestin, J.R. Dorfman, A Course in Statistical Thermodynamics, Academic press, 1971.
8. D. A. McQuarrie, Statistical Thermodynamics, South Asian Edn., 2008.
9. I. Prigogine, Introduction to Thermodynamic Irreversible Processes, 3rd ed.,Wiley Interscience, 1968.
10. S. R. de Groot, P. Mazur, Non-equilibrium Thermodynamics, Dover Publications, 2011.
11. G. Lebon, D. Jou, J. Casas, Understanding Non-equilibrium Thermodynamics, Springer. 2008.
12. S. Kjelstrup, D. Bedeaux, E. Johannessen, J. Gross, Non-Equilibrium Thermodynamics for Engineers: Second Edition, World Scientific Publishing Company, 2017.
13. D. Kondepudi and I. Prigogine, Modern Thermodynamics: From Heat Engines to dissipative Structures, Wiley, New York.

CORE

CHE 2205

THEORETICAL CHEMISTRY-III

(CHEMICAL BONDING AND COMPUTATIONAL CHEMISTRY)

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Explain the quantum mechanical nature of the chemical bond.	Understand
C.O.2: Account for the basic principles and concepts of molecular orbital theory and valence bond theory using quantum mechanical principles.	Apply
C.O.3: Describe quantum mechanically the chemical bonding of any given di- and tri- atomic molecules with molecular orbital theory and valence bond theory.	Analyze
C.O.4: Describe the main similarities and differences between theoretical approaches and identify advantages and disadvantages for modelling various chemical problems.	Apply
C.O.5: Use computational chemistry software to perform and interpret electronic structure calculations.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x						x		
C.O.3	x	x						x		
C.O.4	x	x			x	x	x	x		
C.O. 5	x	x			x		x	x	x	

UNIT – 1 **(8 hrs)**

Chemical bonding, Born Oppenheimer approximation, Valence bond method. Comparison of VB and MO method, LCAO approximation, calculation of energy

levels from wave functions, application to diatomic molecules such as, H_2^+, H_2. Concept of σ, σ*, π, π* orbitals and their characteristics, hybrid orbitals, calculation of coefficients of AO used in sp, sp^2 and sp^3 hybrid orbitals, interpretation of geometry, Valence bond model of H_2, Hybridisation of H_2O,
BF_3, NH_3 and CH_4

UNIT – 2 **(6 hrs)**

Pi bonding in simple molecules, HMO method for linear conjugated hydrocarbons, linear, cyclic, polycyclic, heterocyclic; ethylene, 1,3-butadiene,allyl radical, cation and anion, aromatic hydrocarbons, cyclopropenyl systems, cyclobutadiene, benzene, naphthalene, thiophene. calculation of charge
distribution, bond orders and reactivity.

UNIT – 3 **(6 hrs)**

Tools and philosophy of computational chemistry. potential energy surface - local minima, global minima, saddle point and transition states, geometry optimization-stationary points.

UNIT – 4 **(6 hrs)**

Basis sets, Slater and Gaussian functions, classification of basis sets - minimal, double zeta, triple zeta, split valence, polarization and diffuse basis sets, contracted basis sets, Pople style basis sets and their nomenclature, correlation consistent basis sets.

SCF methods, semiempirical, ab initio, electron correlations, post-Hartree-Fock methods and density functional theory.

UNIT – 5 **(6 hrs)**

Molecular structure, internal coordinates, Cartesian coordinates, geometry optimization, frequency analysis, partial charge, MO, Conformational analysis of ethane and butane

calculation of some simple chemical problems using computational chemistry programme packages

Recommended Text Books:

1. J. P. Lowe, Quantum Chemistry, 3rd ed., Academic Press, New York, 2008.
2. F. Jensen, Introduction to Computational Chemistry, 2nd ed., Wiley, New York, 2009.
3. R. Leach, Molecular Modeling, Principles and Applications, 2nd ed., Pearson Education, London, 2001.
4. A. K. Chandra, Introduction to Quantum Chemistry, 4th ed., Tata McGraw-Hill, 1994.
5. L. Pauling, E. B. Wilson, Introduction to Quantum Mechanics, McGraw-Hill, 1935.
6. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Book ed., Mc.Graw-Hill, New York, 1982.
7. T. A. Albright, J. K. Burdett, M.-H. Whangbo, Orbital Interactions in Chemistry, 2nd ed., John Wiley and Sons, Inc., Hoboken, New Jersey, 2013.

CORE/LAB

CHE 2206

ADVANCED PHYSICAL CHEMISTRY LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Operate various sophisticated instruments.	Apply
C.O.2: Perform experiments based on various laws of physical chemistry.	Apply
C.O.3: I the results obtained from various experiments.	Analyse
C.O.4: Calculate the unknown concentration of the given solution based on the results obtained from the experiment.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	
C.O.2	x	x				x		x	x	
C.O.3	x	x				x		x	x	
C.O.4	x	x		x				x	x	

UNIT – 1 **(96 hrs)**

i. Molecular weight determination by cryoscopic methods, Formula of complexes.
ii. Phase diagrams: Two component liquid–liquid and solid-liquid systems. Three component liquid-liquid systems.
iii. Determination of transition temperature, molecular weight determination.
iv. Refractometry: Variation of refractive index with composition, formula of complexes.
v. Chemical Kinetics: Acid and base catalysed hydrolysis of esters,

vi. Dependence of temperature and ionic strength on the rate of reactions, Hydrolysis of p-nitrophenyl acetate using spectrophotometry.

vii. Ostwald Viscometer: Viscosity of liquid and liquid mixtures.

viii. Conductometry: Cell constant, conductivity of a weak-acid, solubility of a sparingly soluble salt, conductometric titrations. Determination of critical micelle concentration of colloids.

ix. Potentiometry: Measurement of electrode potentials, activity coefficients and potentiometric titrations, pH metric titrations.

x. Adsorption: Checking the validity of Freundlich and Langmuir adsorption and determination of unknown concentration.

xi. Spectrophotometry: Checking the validity of beer Lambert's law and determination of unknown concentration.

xii. Demonstration of instrumentation of AAS, Flame photometry, Fluorescence spectrometer, GPC, Electrochemical work station etc.

Recommended Text Books:

6. A. Findlay, Practical Physical Chemistry, 9th ed., Longman, 1973.
7. D. P. Shoemaker, C.W. Garland, J.W, Nibler, Experiments in Physical Chemistry, 5th ed., McGraw Hill, 1989.
8. J. B. Yadav, Advanced Practical Physical Chemistry, 36th ed., Krishna Prakashan Media (P) Ltd, 2016.
9. J. N. Gurtu, A.N. Gurtu, Advanced Physical Chemistry Experiments, 6th ed., Pragati, 2014.

CORE/LAB

CHE 2207

OPEN ENDED LAB-I

Credit 0

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validating the hypothesis and submit Research Progress Report

ELECTIVE

CHE 2208

BIOANALYTICAL CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Demonstrate key features and characteristics of major biomolecules.	Understand
C.O.2: Describe and explain the principles and applications of MRI and NMR for bioanalysis.	Understand
C.O.3: Outline the principles and theory of major types of electrophoresis and electrophoretic separation.	Apply
C.O.4: Explain the theory and applications of biochemical analysis like RIA, ELISA.	Analyze
C.O.5: Appreciate the variety of popular methods to separate and isolate biomolecules.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x				x		x		
C.O.3	x	x				x		x		
C.O.4	x	x				x		x		
C.O.5	x	x				x		x		

UNIT – 1 **(10 hrs)**

Biomolecules- amino acid, protein, nucleic acid –structures, physical and chemical properties, features and characteristics of major biomolecules, structure-function relationship, significance. Different methods for the estimation of protein. Transition metals in health and disease - Importance of transition metals in physiological processes, Therapeutic implications of transition metals.

UNIT – 2 **(8 hrs)**

Transmission electron Microscopy (TEM), Scanning electron Microscopy (SEM) – Instrumentation and its biological applications. Nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI) technologies: key tools for the life and health sciences. Principles of NMR and the importance of this biomolecular analytical technique. Established and emerging applications of NMR. Principles and uses of MRI. MRI as a principal diagnostic and research tool.

UNIT – 3 **(4 hrs)**

Electrophoretic techniques – Principles of electrophoretic separation. Types of electrophoresis including paper, gel. Electroporation, Pulse field gel electrophoresis- applications in life and health science.

UNIT – 4 **(4 hrs)**

Radio immune assay (RIA) - principle and applications. Enzyme linked immune sorbent assay (ELISA) principle and applications. Biosensors-applications.

UNIT – 5 **(6 hrs)**

Principle of centrifugation, concept of RCF, features and component of major types of centrifuge, preparative, differential and density gradient centrifugation, analytical ultra-centrifugation, centrifugation. Flow cytometry: principles and applications of this core method of separation.

Recommended Text Books:

1. V. A. Gault, N. H. Mcclenaghan, Understanding bio analytical chemistry - principle and applications, John Wiley and Sons, Ltd Publications, 2009.
2. A. Manz, N. Pamme, D. Iossifidis, Bio-analytical Chemistry, 2004
3. S. R. Mikkelsen, E. Corton, Bio Analytical Chemistry, John Wiley and Sons, Ltd Publications, 2004.
4. K. Wilson, J. Walker, Practical Biochemistry-Principles and techniques, 5th ed., Cambridge University press, 2000.

ELECTIVE

CHE 2209

POLYMER CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Recognise the concept of macromolecules and describe the classification, synthesis and process technologies involved in common polymers.	Understand
C.O.2: Analyse the kinetics and mechanism involved in different types of polymerization	Analyse
C.O.3: Apply the concepts of stereochemical aspects and analyse the conformation and configuration of polymers	Analyse
C.O.4: Apply different characterisation techniques to identify polymers.	Apply
C.O.5: Explain the synthesis, structure and applications of industrial polymers.	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x		x						x	
C.O.2					x					
C.O.3	x	x							x	x
C.O.4						x	x			

UNIT – 1 **(6 hrs)**

Raw Material sources of polymers. Natural gas, coal and petroleum. Monomers and polymers derived from natural gas. Petroleum and petrochemicals. Monomers and polymers derived from ethylene and propylene. Monomers and polymers derived from C4 and C5 Systems and BTX fraction. Acetylene as a source of monomers.

UNIT – 2 **(8 hrs)**

Polymerization processes. Free radical addition polymerization. Kinetics and mechanism. Chain transfer. Molecular weight distribution and molecular weight control. Cationic and anionic polymerization. Polymerization without termination. Living polymers. Step Growth polymerization. Kinetics andmechanism. Linear Vs cyclic polymerization, Group Transfer, metathesis and ring opening polymerization. Copolymerization. The copolymerization equation, Q-e scheme, Gelation and Crosslinking. Copolymer composition drift. Polymerization techniques. Bulk Solution, melt, suspension, emulsion and dispersion techniques.

UNIT – 3 **(8 hrs)**

Polymer Stereochemistry. Organizational features of polymer chains. Configuration and conformation, Tacticity, Repeating units with more than one asymmetric center. Chiral polymers – main chain and side chain. Stereoregular polymers. Manipulation of polymerization processes. Zeigler-Natta and Kaminsky routes. Coordination polymerization. Metallocene and Metal oxide catalysts.

UNIT – 4 **(6 hrs)**

Polymer Characterization. Molecular weights. Concept of average molecular weights, Determination of molecular weights. GPC and Light scatteringtechniques. Molecular weight distribution. Crystalline and amorphous states. Glassy and Rubbery States. Glass transition and crystalline melting. Spherullites and Lammellae. Degree of Crystallinity, Thermal analysis of polymers. TG/DTG, DTA/DSC, Spectroscopy of polymers. Microstructure determination by IR, Raman, UV, NMR and MS techniques. Solid State NMR and polymer stereochemistry.

UNIT – 5 **(4 hrs)**

Industrial polymers. Synthesis, Structure and applications. Polyethylene, polypropylene, polystyrene. PVC, PVA, PAN, PA. Poly(vinyl carbazole), poly(vinyl imidazole). PMMA and related polymers. Flourine containingpolymers. Reaction polymers. Polyamides, polyesters. Epoxides, polyurethanes, polycarbonates, phenolics, PEEK, Silicone polymers. Reactions of polymers.

Recommended Text Books:

1. Billmayer, F.W. Textbook of Polymer Science. 3rd Ed., Wiley. N.Y.1991.
2. Cowie, J.M.G. Polymers: Physics and Chemistry of Modern Materials. Blackie. London,1992.
3. Young, R.J. Principles of Polymer Science, 3rd Ed., Chapman and Hall. N.Y.1991.
4. Flory, P.J. A Text Book of Polymer Science. Cornell University Press. Ithacka, 1953.
5. Ullrich, F. Industrial Polymers, Kluwer, N.Y.1993.
6. Elias, H.G. Macromolecules, Vol. I & II, Academic, N.Y.1991.
7. Brydson, J.A. Polymer chemistry of Plastics and Rubbers, ILIFFE Books Ltd., London,1966

ELECTIVE

CHE 2210

ADVANCED PHOTOCHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe various photochemical and photophysical processes and apply established experimental methods for the investigation of these processes.	Apply
C.O.2: Explain theories of photoinduced electron transfer and reactivity of excited states and their significance in different fieldsincluding biomedical applications and photosynthesis.	Evaluate
C.O.3: Apply the knowledge of photochemistry of semiconductors and advanced materials for various applications involving photochemical energy conversions.	Apply
C.O.4: Explain theory and application of photocatalysis and explain the environmental impact of atmospheric photochemistry.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x						x		
C.O.3	x	x			x			x		
C.O.4	x	x	x		x			x		

UNIT – 1 **(8 hrs)**

Energy Transfer-Theories of Energy Transfer – Photosensitization of Organic and Inorganic Molecules – Singlet Oxygen – Methods of singlet oxygen generation and Detection – Chemistry of Singlet Oxygen – Photodynamic Therapy of Cancer.

UNIT – 2 **(8 hrs)**

Photoinduced Electron Transfer – Theory of Electron transfer – Circumventing Back Electron transfer – Photoinduced Electron transfer reactions of Organic and Inorganic Molecules – Photosynthesis.

UNIT – 3 **(4 hrs)**

Photochemistry and Photophysics of Semiconductors – Semiconductor Photocatalysis and applications. Atmospheric photochemistry

UNIT – 4 **(6 hrs)**

Photochemistry and Advanced Materials - Artificial Solar Energy Harvesting – Photochemical Splitting of Water – Dye sensitized solar cells - Grätzel Cell - Bulk heterojunction devices for solar energy harvesting - Organic light emitting devices. Photoresists – Photolithography – Photochromism – Photonic Materials and Lasers.

UNIT – 5 **(6 hrs)**

Photochemistry in Practice – Radiometry and Actinometry – Principles of Radiometry and radiometers – Actinometry – Quantum Yields – Light Sources – Optical Materials and Filters – Photochemical Reactors.

Recommended Text Books:

1. N. J. Turro, V. Ramamurthy, J. C. Scaiano, Modern Molecular Photochemistry of Organic Molecules, University Science Books, 2010.
2. C.E. Wayne, Photochemistry (Oxford Chemistry Primers), Oxford University Press; 1st ed., 1996.
3. J. R. Lakowicz, Principles of Fluorescence Spectroscopy, Plenum Press, 3rd ed., 2010.
4. A. M. Braun, M.-T. Maurette, Esther Oliveros, Photochemical Technology, John Wiley & Sons, 1991.
5. M. A. Fox, M. Chanon, Photoinduced Electron Transfer Part A, B. C and D, Elsevier Science Publishing Company, 1988.
6. J. Mattay Ed., Photoinduced Electron Transfer 1-5 (Topics in Current Chemistry), Springer, 1st ed., 1990-1993.

7. G. J. Kavarnos, Fundamentals of Photoinduced Electron Transfer, 1st ed., Wiley-VCH, 1993.
8. V. Ramamurthy, K. Schanze, Molecular and Supramolecular Photochemistry, Volume 10, Semiconductor Photochemistry and Photophysics, Marcel Dekker, New York, 2003.
9. V. Ramamurthy, Photochemistry in Organized and Confined Media, VCH Publishers, New York, 1991.

ELECTIVE

CHE 2211

THEORY OF ORBITAL INTERACTIONS IN CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Examine the physical properties associated with molecules and the pathways taken by chemical reactions.	Analyse
C.O.2: Correlate qualitatively the shape and energy of orbitals and the chemical reaction exhibited by any molecule.	Apply
C.O.3: Explore the effects of symmetry, overlap, and electronegativity in the molecular orbital in case of chemical reaction.	Evaluate
C.O. 4: Explore the structures and reactivity relationships associated with any molecule.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		

UNIT – 1 **(6 hrs)**

Atomic and Molecular Orbitals, Concepts of Bonding and Orbital Interaction, Orbital Interaction Energy, Molecular Orbital Coefficients, Electron Density Distribution, Perturbational Molecular Orbital Theory, Linear H_3, HF, and the Three-Orbital Problem.

UNIT – 2 **(10 hrs)**

Molecular Orbital Construction from Fragment Orbitals, Triangular H_3, Rectangular and Square Planar H_4, Tetrahedral and Linear H_4, Pentagonal H_5 and Hexagonal H_6, Molecular Orbitals of Diatomic Molecules and Electronegativity Perturbation, Geometrical Perturbation of Molecular orbitals, Molecular Orbitals of AH_2, Walsh Diagrams, Jahn–Teller Distortions.

UNIT – 3 **(6 hrs)**

Molecular Orbitals of Small Building Blocks, AH System, AH_3 Systems, pi-Bonding Effects of Ligands, AH_4 System, Molecules with Two Heavy Atoms, A_2H_6 Systems, Orbital Interactions through Space and through Bonds.

UNIT – 4 **(4 hrs)**

Polyenes and Conjugated Systems, Acyclic Polyenes, Huckel Theory, Cyclic Systems, Conjugation in Three Dimensions, Solids, Energy Bands, Hypervalent Molecules.

UNIT – 5 **(6 hrs)**

Transition Metal Complexes. Octahedral ML_6, pi-Effects in an Octahedron, Distortions from an Octahedral Geometry, Square Planar, Tetrahedral ML_4 Complexes, Five Coordination, Square Pyramidal ML_5 Fragment, ML_3 Fragment, ML_2 and ML_4 Fragments, M_2L_8 Dimers, CpM and Cp_2M, Isolobal Analogy.

Recommended Text Books:

1. T. A. Albright, J. K. Burdett, M.-H. Whangbo, Orbital Interactions in Chemistry, 2nd ed., John Wiley and Sons, Inc., Hoboken, New Jersey, 2013.
2. I. Flemming, Molecular Orbitals and Organic Chemical Reactions, Students ed., Wiley, 2009.
3. A. Rauk, Orbital Interaction Theory of Organic Chemistry, 2nd ed., Wiley-Blackwell, 2000.
4. W. L. Jorgensen, L. Salem, The Organic Chemist's Book of Orbitals, Academic Press, 1973.

MOOC ELECTIVE

CHE 2212

CHEMICAL CRYSTALLOGRAPHY

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Apply the concepts and applications of widely used experimental technique of X-ray crystallography	Analyse
C.O.2: Describe the wider significance of symmetry operation in understanding the crystal structure	Apply
C.O.3: Understand the experimental techniques for crystal preparation and selection	Understand
C.O.4: Understand the theoretical calculations involved in extracting structural information from diffraction patterns	Understand
C.O.5: Perform structure determination and refinement of crystal structures using x-ray diffraction data and software packages.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x		x		
C.O.2	x	x				x		x		
C.O.3	x	x					x	x		
C.O.4	x	x						x		
C.O.5	x	x				x	x	x		

UNIT – 1 **(12 hrs)**

Introduction, 1D symmetry, Concept of 2D symmetry and lattices, notations of symmetry elements, space groups in 2D, 3D lattices, 32 point groups and their notations, crystal systems and Bravais lattices. Stereographic projections, Laue symmetry; glide planes, screw axes and their notations, space groups, equivalent points, space group symmetry diagrams etc. Miller Indices, crystallographic planes and directions, close pack structures, linear density, planar density, Miller-Bravais indices for hexagonal systems, various ceramic structures (NaCl, ZnS, CaF2, CsCl etc.), octahedral and tetrahedral sites.

UNIT – 2 **(12 hrs)**

What are X-rays, generation and classification of X-ray, X-ray sources, diffraction of X-rays, Bragg's law. The reciprocal lattice, reciprocal relationship, Bragg's law in reciprocal space, Ewald's sphere and sphere of reflection , Methods of crystal growth, identification of phases and morphologies, in-situ cryo crystallization, crystal growth under external stimuli etc.

UNIT – 3 **(12 hrs)**

Data collection strategies, Laue Method, Oscillation, rotation and precession methods. L-P corrections, structure factor, scaling, interpretation of intensity data, temperature factor, symmetry from intensity statistics, Structure factor and Fourier synthesis, Friedel's law; exponential, vector and general forms of structure factor, determination of systematic absences for various symmetry or lattice centering, FFT, Anomalous scattering and absolute configuration.

UNIT – 4 **(12 hrs)**

Phase problem, Direct Methods, structure invariants and semi invariants, probability methods, Phase determination in practice, Patterson Methods, Patterson Symmetry, completion of structure solution, ΔF synthesis**,** Refinement by Fourier synthesis, refinement by ΔF synthesis, Refinement by least squares method, weighting functions, Goodness-of-Fit (GOF) parameter, treatment of non-hydrogen atoms, and treatment of hydrogen atoms, treatment of disordered structures.

UNIT – 5 **(16 hrs)**

Crystal selection, indexing of crystals, data collection, data reduction, space group determination, structure solution and refinement using SHELXS97 and SHELXL97, introduction to crystallographic packages (APEX II suite, OLEX2, WinGx, PLATON) and IUCr validation of the data, Methodology, geometrical basis of powder X-ray diffraction, applications of PXRD: determination of accurate lattice parameters, identification of new/unknown phases, applications in pharmaceutical industry. Applications of powder X-ray diffraction: Structure determination from PXRD and Reitveld method for structure refinement, indexing of PXRD, handling of PXRD using DASH.

Recommended Text Books:

1. X-ray structure determination: A Practical Guide (2nd Ed.) by George H. Stout and Lyle H Jensen, Wiley-Interscience, 1989.
2. Fundamentals of Crystallography (2nd Ed.) by C. Giacovazzo, Oxford University Press, 2002
3. X-ray analysis and The Structure of Organic Molecules (2nd Ed.) Wiley-VCH, 1996
4. Chemical Applications of Group Theory (3rd Ed.) by F. A. Cotton, Wiley-India Edition, 2009.
5. The Basics of Crystallography and Diffraction by Christopher Hammond. Oxford University Press, 2015
6. Crystal Structure analysis A Primer by Jenny Pickworth Glusker and Kenneth N. Trueblood, Oxford University Press, 2010
7. Crystal Structure Analysis Principles and Practices by A. J. Blake, W. Clegg, J. M. Cole, J. S. O. Evans, P. Main, S. Persons and D. J. Watkin. Oxford University Press, 2009
8. Crystal Structure Refinement A Crystallographer's Guide of SHELXL by P. Muller, R. Herbst-Irmer, A. L. Spek, T. R. Schneider and M. R. Sawaya, Oxford University Press, 2006
9. Crystal Structure Determination by Werner Massa. Springer, 2013.

SWAYAM

Prof. Angshuman Roy Choudhury

IISER,Mohali

CORE

CHE 2301

ADVANCED ANALYTICAL CHEMISTRY AND INSTRUMENTAL METHODS

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Explain the theory, instrumentation and applications of various electroanalytical techniques, chromatographic, thermal and surface analysis	Apply
C.O.2: Predict appropriate chromatographic methodology for separation of a given mixture	Analyse
C.O.3: Perform separation of components in a mixture using GC-MS and HPLC	Evaluate
C.O.4 : Perform individual and simultaneous voltammetric analysis of samples	Evaluate
C.O. 5 : Analyse the surface of various samples using SEM, AFM, TEM	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X									
C.O.2	X	X								
C.O.3	X	X	X	X		X	X		X	
C.O.4	X	X	X	X		X	X		X	
C.O. 5	X	X	X	X						

UNIT – 1 **(18 hrs)**

Potentiometry: different types of indicator electrodes, limitations of glass electrode, applications in pH measurements, other types of ion selective electrodes, solid, liquid, gas sensing and specific types of electrodes, biomembrane, biological and biocatalytic electrodes as biosensors, importance of selectivity coefficients. CHEMFETS- importance of specially designed amplifier systems for ion selective electrode systems. Potentiometric titrations- types and applications.

Electrogravimetry- electrogravimetry without potential control, controlled potential electrogravimetry, applications

Coulometry- constant current and constant potential coulometry, applications- primary and secondary coulometry, advantages of coulometric titrations

Conductance measurement – conductometric titrations

Polarography – current – voltage curve, DME-components of polarographic current, supporting electrolyte, polarographic maxima. Half-wave potential, Applications of Polarography

Voltammetry - different types, Theory and applications

Stripping analysis. Amperometric titrations – Different types and Applications

Impedance spectroscopy, Voltammetric sensors – individual and simultaneous analysis-Case study

UNIT – 2 **(12 hrs)**

Gas chromatography – basic instrumental set up-inlets, carriers, columns, detectors and comparative study of TCD, FID, ECD, NPD and MS. Qualitative and quantitative studies using GC, Preparation of GC columns, packet columns and capillary columns, selection of stationary phases of GLC, Choosing theparameters- Temperature, Length of the column, Sample size, Flow rate

CHN analysis by GC, Case study

GC Capillary electrophoresis-migration rates and plate heights, instrumentation, sample introduction, detection methods, applications. Capillary gelelectrophoresis. Capillary isotachophoresis. Isoelectric focusing.

Capillary electro chromatography-packed columns. Micellar electro kinetic chromatography.

and GC-MS applications

UNIT – 3 **(12 hrs)**

HPLC – Separation process, Eddy diffusion, Mass transfer, Longitudinal diffusion, Retention parameters in HPLC-Capacity factor, Retention time, Retention volume, Peak width, Total number of theoretical plates, Height equivalent of a theoretical plate, Resolution and retention time, Solvent delivery systems, Detectors

Instrumentation and functioning of HPLC, Types of HPLC - Modes of separation in HPLC-adsorption chromatography, reversed phase chromatography, ion pair chromatography, ion exchange chromatography Solubility and retention in HPLC Method development in HPLC - Selection of mobile phase and optimization, Preparation of sample, Selection of column and solvent

HPLC method validation, HPLC Analysis -Case study Dos and Don’ts in HPLC - Troubleshooting in HPLC

UNIT – 4 **(12 hrs)**

Measurement of alpha, beta, and gamma radiations, neutron activation analysis and its applications. Principle and applications of isotope dilution methods, Radioimmunoassay (RIA), Immunoradiometric assay (IRMA), Enzyme linked immunosorbent assay (ELISA)-Principles and practical aspects

Thermal methods of Analysis TG, DTA and DSC - Instrumentation and Theory – Factors affecting TGA - effect of atmosphere on DTA. TG of copper sulphate pentahydrate and calcium oxalate monohydrate. Application of thermal methods for identification of substances.

UNIT – 5 **(10 hrs)**

Chemical Analysis of surfaces: Surface preparations-ion scattering spectrometrysecondary ion scattering microscopy (SIMS)-Auger election spectroscopy-ESCA instrumentation and application.

Principle, instrumentation and applications of SEM, TEM and AFM, Case study

Recommended Text Books:

1. J.M. Mermet, M. Otto, R. Kellner, Analytical Chemistry, Wiley-VCH, 2004.
2. D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8th Edn., Saunders College Pub., 2007.
3. J.G. Dick, Analytical Chemistry, R.E. Krieger Pub., 1978.
4. J.H. Kennedy, Analytical Chemistry: Principles, Saunders College Pub., 1990.
5. G.H. Jeffery, J. Bassett, J. Mendham, R.C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Edn., John Wiley& sons,1989.
6. C.L. Wilson, D.W. Wilson, Comprehensive Analytical Chemistry, Elsevier, 1982.
7. G.D. Christian, J.E. O'Reilly, Instrumental Analysis, Allyn & Bacon, 1986.
8. R.A. Day, A.L. Underwood, Quantitative Analysis, Prentice Hall, 1967.
9. H.A. Laitinen, W.E. Harris, Chemical Analysis, McGraw Hill, 1975.
10. F.W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, Blackwell Science, 2000.
11. Contemporary Instrumental Analysis, Kenneth A. Rubinson, Judith F. Rubinson, Prentice Hall, New Jersey, 2000.
12. Wilson & Wilson's, Comprehensive Analytical Chemistry, Volume 47, Modern Instrumental Analysis, Edited by S. Ahuja, N. Jespersen, Reed Elsevier India Private Ltd., Noida, 2006.
13. Journal of Chromatography Library, Volume 3, Liquid Column Chromatography-A Survey of Modern Techniques and Applications, Edited by Z. Deyl, K. Macek, J. Janak, Elsevier Scientific Publishing Company, Amsterdam, 1975.
14. Gas Chromatography, John Willett, John Wiley & Sons, Singapore, 1991.
15. Fundamentals of Analytical Chemistry, Doughlas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch, 9th Ed., Cengage Learning, 2014.
16. Allen J. Bard, Larry R. Faulkner, Electrochemical Methods-Fundamentals and Applications, John Wiley & Sons, New York, 1980.

CORE

CHE 2302

Inorganic Chemistry – III

(ORGANOMETALLIC AND BIOINORGANIC CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: distinguish the different types of ligands with respect to the type of interaction with the metal.	Analyse
C.O. 2: evaluate the structure, bonding and reactions of organometallic compounds and metal clusters.	Evaluate
C.O.3: predict the stability of organometallic compounds and metal clusters.	Apply
C.O.4: explain the application of reactions of organometallic complexes in homogeneous catalytic processes.	Apply
C.O.5: identify the role of metals in biological systems.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		
C.O.5	x	x						x		

UNIT – 1 **(8 hrs)**

Compounds with transition metal to carbon bonds: eighteen electron rule; classification of ligands, nomenclature, σ donor ligands – metal alkyl, aryl complexes; σ donor/π acceptor ligands, – metal alkenyls, alkynyls, carbenes, carbynes, carbonyls, isocyanide, fluxionality of ligands – structure, bonding, spectra, preparation and reactions.

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UNIT – 2 **(8 hrs)**

σ, π donor/π acceptor ligands – olefin complexes, alkyne, allyl, enyl complexes, metallocene- ferrocene, titanocene, zircanocene, arene complexes, cycloheptatriene, cyclooctatetraene, cyclobutadiene complexes, fluxionality of ligands – structure, bonding, preparation, reactions and spectroscopy

UNIT – 3 **(8 hrs)**

Metal–Metal bonds and Transition metal clusters; preparation, properties and spectroscopy. Parallels with nonmetal chemistry- isolobal analogy. Application of Wade-Mingos-Lauher rules in predicting the structure of organometallic clusters

UNIT – 4 **(12 hrs)**

Reactions of organometallic complexes – Ligand cone angle, oxidative addition, reductive elimination, insertion, nucleophilic and electrophilic attack of coordinated ligands. Homogeneous catalysis using organometallic compounds: olefin hydrogenation, hydroformylation, Wacker process, Ziegler-Natta polymerisation, cyclo oligomerisation, olefin isomerisation, olefin metathesis, Monsanto acetic acid synthesis, Fischer-Tropsch process, hydrosilylation, coupling reactions in organic chemistry

UNIT – 5 **(12 hrs)**

Metal ions in biological systems: Heme proteins – hemoglobin, myoglobin

Non-Heme Iron Proteins: Iron storage and transfer – ferritin, transferrin; electron transfer (Iron-sulfur protein) – rubredoxin, ferredoxin; O_2 transport – hemerythrin

Copper proteins and Enzymes – Hemocyanin, superoxide dismutase, ceruloplasmin, cytochrome co-oxidase;

Zinc and Cobalt enzymes – carbonic anhydrase, carboxypeptidase, interchangeability of zinc and cobalt enzymes; Vitamin B12 and B12

Photosynthesis and N2 fixation Metals in medicines and therapy

Recommended Text Books:

1. Ch. Elschenbroich, A. Salzer, Organometallics – A Concise Introduction, VCH Publishers, 1989.
2. B. D. Gupta, A. J. Elias, "Basic Organometallic Chemistry", University Press, 2010.
3. P. Powell, Principles of Organometallic Chemistry, 2nd ed., ELBS, 1991.
4. J. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
5. E.-I. Ochiai. Bioinorganic Chemistry – An Introduction, Allyn and Bacon Inc., 1977.
6. N. Kaim, B. Schwederski. Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, John Wiley, 1994.
7. Bertini, H. B. Gray, S. J. Lippard, J. S. Valentine, Bioinorganic Chemistry, Viva Books, 1998.
8. R. W. Hay, Bio Inorganic Chemistry, Ellis Horwood, 1987.
9. J. A. Cowan, Inorganic Biochemistry – An Introduction, 2nd ed., VCH, 1997.
10. N. S. Hosmane (Ed) Boron Science: New Technologies and Applications, CRC Press, 2011.
11. S. J. Lippard, J. M. Berg. Principles of Bioorganic Chemistry, Panima Publ. Corpn. 2005.
12. M. N. Hughes, The Inorganic Chemistry of Biological Processes, Wiley, 1981.

CORE

CHE 2303

ORGANIC CHEMISTRY-IV

(CHEMISTRY OF NATURAL PRODUCTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Device synthesis scheme for heterocyclic aromatic and nonaromatic organic compounds.	Analyse
C.O.2: Elucidate structure and device synthesis for important natural products.	Apply
C.O.3: Describe molecular structure of carbohydrates, proteins, DNA, RNA and synthesis of vitamin C and shikimic acid.	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x	x					x		
C.O.2	x	x	x					x		
C.O.3	x	x	x					x		

UNIT – 1 **(6 hrs)**

Nomenclature and general characteristics of heterocyclic compounds. Structure, properties, synthesis and reactivity of three and four-membered ring heterocycles containing one heteroatom.

UNIT – 2 **(10 hrs)**

Heteroaromatic compounds (five and six-membered rings) containing one or two heteroatoms. Fused ring compounds: Synthesis and properties of indole, quinoline, isoquinoline, coumarin, flavone, purine and pyrimidine bases present in nucleosides.

UNIT – 3 **(12 hrs)**

Terpenoids: Classification, biosynthesis. Structure elucidation and synthesis of abietic acid. Steroids: classification, biosynthesis. Structure elucidation of cholesterol, conversion of cholesterol to progesterone, androsterone and testosterone. Fatty acids: structure, biosynthesis. Prostaglandins-classification, structure, biosynthesis and synthesis.

Alkaloids: Classification, isolation, structure elucidation based on degradative reactions (quinine and atropine). Biosynthesis of quinine and papaverine.

UNIT – 4 **(10 hrs)**

Carbohydrates: Structure of ribose, glucose, fructose, maltose, sucrose, lactose, starch cellulose and cyclodextrins. Preparation of alditols, glycosides (O, C, and N), deoxysugars. Synthesis of Vitamin C from glucose. Nucleic acids: Structure and synthesis, genetic code, recombinant DNA, biosynthesis of shikimic acid.

UNIT – 5 **(10 hrs)**

Amino acids, peptides and enzymes: Synthesis of amino acids – Strecker and azalactone synthesis, enantioselective synthesis of amino acids, reactions of amino acids. Structure of proteins, introduction to enzymes and coenzymes with special reference to the function of chymotrypsin, NAD, thiamine, pyridoxal. In vitro and in vivo synthesis of peptides, solid phase synthesis.

Recommended Text Books:

1. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
2. I. L. Finar, Organic Chemistry Volumes 1 & 2, 6th ed., Pearson Education Asia, 2004.
3. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.

4. N. R. Krishnaswamy, Chemistry of Natural Products; A Unified Approach, Universities Press, 1999.
5. R. J. Simmonds, Chemistry of Biomolecules: An Introduction, RSC, 1992.
6. R. O. C. Norman, Principles of Organic Synthesis, 2nd ed., Chapman and Hall, 1978.
7. J. A. Joule, K. Mills, Heterocyclic Chemistry, 5th ed., Wiley, 1998.
8. J. J. Li, E. J. Corey, Total Synthesis of Natural Products: At the Frontiers of Organic Chemistry, Springer, 2012.
9. T. Eicher, S. Hauptmann, The Chemistry of Heterocycles, 2nd ed., Wiley, 2003.
10. K. C. Nicolaou, S. A. Snyder, Classics in Total Synthesis II: More Targets, Strategies, Methods, Wiley, 2003.

CORE

CHE 2304

PHYSICAL CHEMISTRY-II

(CHEMICAL KINETICS, REACTION DYNAMICS, CATALYSIS AND SURFACE CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Interpret the basic reaction dynamics and obtain the rate constants for reactions in gaseous state and solutions.	Analyse
C.O. 2: Calculate thermodynamic parameters from kinetic data.	Apply
C.O. 3: Interpret the kinetics of unimolecular, termolecular and fast reactions.	Apply
C.O. 4: Identify isotope effects in reactions	Analyse
C.O. 5: Apply the principles of acid-base and enzyme catalysis to solve any given kinetic data.	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X	X			X					
C.O.2	X	X			X					
C.O.3	X	X			X					
C.O.4	X	X			X					
C.O.5	X	X			X					

UNIT – 1 **(8 hrs)**

Complex Reactions- Parallel, Consecutive and Opposing reactions, Steady state Approximation, Kinetics of chain reactions - Photochemical reactions H_2-Cl_2 and H_2-Br_2 reaction, Organic decomposition reactions-Rice Herzfield mechanism (acetaldehyde and ethane), Branched Chain Reactions, Explosions-

Semenov Hinshelwood mechanism (H_2-O_2 reaction),

Fast Reactions- Relaxation methods- Perturbations, Flash photolysis and Pulse radiolysis

UNIT – 2 **(10 hrs)**

Molecular reaction dynamics: Reactive encounters, Theories of reaction rates- Collision Theory. Collision and reaction cross section. Activated Complex Theory- PES, Erying equation, Comparative evaluation of collision and transition state theory, Thermodynamic treatment of reaction rates. Theory of unimolecular reactions- Lindemann Mechanism, Modifications to Lindemann mechanism- Hinshelwood, RRK and RRKM model. Termolecular reactions.

Molecular beam methods, Stripping and rebound mechanism

UNIT – 3 **(10 hrs)**

Reactions in Solutions – Cage effect, Transition state theory for reactions in solutions, Effect of ionic strength, dielectric constant and Internal pressure. Primary and secondary salt effect. Solute-solvent interactions. Ion dipole and dipole-dipole reactions. Diffusion controlled reactions.

Isotope effects: Equilibrium isotope effects. Primary and Secondary kinetic isotope effects.

UNIT – 4 **(10 hrs)**

Surfaces and interfaces: Surface free energy and Surface tension, Contact angles and Wetting, Surface films. capillarity, vapour pressure of droplets-Kelvin equation. pressure difference across curved surface -Laplace equation, Surface wetting- hydrophilicity and hydrophobicity.

Physical and chemical adsorption. Adsorption isotherms- Langmuir (kinetic and statistical derivation), Freundlich and BET (derivation) isotherms, Determination of surface area using Langmuir and BET isotherms, Isosteric heat of adsorption. Thermodynamics of adsorption- Gibbs adsorption isotherm.

UNIT – 5 **(10 hrs)**

Catalysis and Inhibition, heterogeneous Catalysis – Transition state theory, General mechanism. General Mechanism of homogeneous catalysis- Arrhenius and vant Hoff intermediates, Acid base catalysis- specific and general acid catalysis, Enzyme catalysis- Michaelis-Menten Mechanism, Competitive and non competitive inhibition. Unimolecular and bimolecular Surface reactions- Kinetics of adsorption- Langmuir Hinshelwood mechanism and Rideal-Eley mechanism.

Autocatalysis- Oscillatory reactions- Lotka- Volterra, Oregonator, Brussellator.

Recommended Text Books:

1. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York.
2. K. J. Laidler, Chemical-Kinetics, McGraw Hill, New York.
3. M. R. Wright, An Introduction to Chemical Kinetics, Wiley, 2004.
4. Richard Masel, Chemical kinetics and Catalysis, Wiley Interscience.
5. P. W. Atkins, Physical Chemistry 8th Edn., Wiley, New York.
6. Christian Reichardt, Solvents and Solvent effects in Organic Chemistry, Wiley VCH 2003.
7. A. W. Adamson, The Physical Chemistry of Surfaces, 2nd Edn., Wiley. New York.
8. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York.
9. K. J. Laidler, Chemical-Kinetics, McGraw Hill, New York.
10. M. R. Wright, An Introduction to Chemical Kinetics, Wiley, 2004.
11. A. Somorjai, Chemistry of Surfaces, 3rd Edn. Wiley, New York.
12. Clark, “Theory of adsorption and catalysis”, Academic Press, 1970.
13. J.M. Thomas & W.J. Thomas, “Introduction to principles of heterogeneous catalysis”, Academic Press, New York, 1967.
14. R.H.P. Gasser, “An introduction to chemisorption and catalysis by metals”, Oxford, 1985.
15. D.K Chakraborthy, “Adsorption and catalysis by solids”, Wiley Eastern Ltd. 1990.

CORE

CHE 2305

PHYSICAL CHEMISTRY-III

ADVANCED ELECTROCHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: describe the theories effecting ionic conductance and apply the concepts to calculate conductance behaviour of a given system.	Apply
C.O.2: describe the electronic conductance behaviour in charged interfaces and analyse the catalytic behaviour of a system.	Analyse
C.O.3: learn the working principle and advancement in futuristic electrochemical devices.	Understand

	Programme Outcomes							
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6	P.O.7	P.O.8
C.O.1	x	x						x
C.O.2	x	x						x
C.O.3	x	x				x		x

UNIT – 1 **(6 hrs)**

Review of basic concepts, Ionic Conductance, Ion Solvent Interactions, Ion-Water Interactions, Coordination Number, Solvation numbers, Hydration of simple cation, anion, and transition metal ion. Ion-Ion Interaction, Debye-HuckelTheory, Ionic Atmosphere, time of Relaxation, Mechanism of Electrolytic Conductance, Linearized P-B equation, Activity and Activity Coefficient of Electrolytes, Validity of Deby-Huckel theory., Debye-Hückel limiting law, Debye-Hückel-Bronsted Equation.

UNIT – 2 **(8 hrs)**

Ion transport, Fick's law of diffusion, Diffusion Coefficient, Ionic drift in presence of electric field, drift velocity, transport number, Debye-Huckel- Onsager Equation, Relaxation effect, time of relaxation, Determination of degree of dissociation, Debye-Falkenhagen Effect, Wien Effect.

Ionic liquids, Limiting case of zero solvent-pure electrolyte, features of ionic liquid, diffusion in IL, ionic conductance IL, liquid oxide electrolytes.

UNIT – 3 **(8 hrs)**

Electrodics, Charged Interfaces, Electrode Potential, Factors Influencing electrode potential, Band Bending, electrolytic polarization, dissolution and decomposition potential, concentration polarization. Concentration cells.

Structure of electrified interfaces, liquid junction potential, the electrode double layer, electrode-electrolyte interface, different models of double layer, theory of multilayer capacity, electrocapillary, Lippmann equation, membrane potential

UNIT – 4 **(6 hrs)**

Electrode kinetics, Ion adsorption, Electron Transfer Under an Interfacial Electric Field, Overvoltage, theories of overvoltage, Tafel equation, Butler-Volmer equation. Electrocatalyst- Homogeneous, heterogeneous, Randles-Sevcik Equations, Pourbiax diagrams, PCET.

UNIT – 5 **(4 hrs)**

Semiconductor electrode interface. Band bending, photoelectrochemistry, fuel cells, battery-metal –ion, metal-air battery, Corrosion, Bioelectrochemistry – nervous system, enzyme as electrodes.

Recommended Text Books:

1. J. Bockris, A. K. N. Reddy, Modern Electrochemistry-1 Ionics, 2nd ed., Springer Science & Business Media, 2018.
2. J. Bockris, A. K. N. Reddy, M. E. Gamboa-Aldeco, Modern Electrochemistry-2A: Fundamentals of Electrodics, 2nd ed., Springer Science & Business Media, 2018.
3. J. Bockris, A. K. N. Reddy, Modern Electrochemistry 2B: Electrodics in Chemistry, Engineering, Biology and Environmental Science, 2nd ed., Springer Science & Business Media, 2018.
4. R. Crow, Principles and Applications of Electrochemistry, 4th ed., 1994.
5. S. Glasstone, An Introduction to Electrochemistry, Paperback ed., 2007.

CORE/LAB

CHE 2306

OPEN ENDED LAB-III

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validating the hypothesis.

The students shall submit a project report and appear for viva-voce.

ELECTIVE

CHE 2308

OLEOCHEMICALS, NUTRACEUTICALS AND SURFACTANT TECHNOLOGY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Able to classify and demonstrate the use of oils.	Apply
C.O.2: Analyse and characterize oleocemicals, nutraceuticals and surfactants.	Analyse
C.O.3: Evaluate the techniques of preparation and purification of oils.	Evaluate
C.O.4: Prepare formulation of soaps, detergents and cosmetics.	Create

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x		x				x		
C.O.3	x	x					x	x		
C.O.4	x	x	x		x			x		

UNIT – 1 **(8 hrs)**

General Introduction, Sources of edible oils and fats, Processing and refining, Stability and Antioxidants, Analysis testing and QC. Introduction to essential oils and comparison with other oils. Raw materials, processing, purification and isolation of essential oil, Conventional and advance methods of production of essential oils, Synthetic Aroma chemicals and aromatherapy, Physicochemical and sensory Analysis and quality control in industry , Detail study of selected essential oils related to production, isolation, applications etc. (3 examples), Applications in soaps, detergents, cosmetics industry, flavors etc. Oleochemical

Industry and Market Information.

UNIT – 2 **(8 hrs)**

Introduction to nutraceuticals: definitions, synonymous terms, claims for a compound as nutraceutical, regulatory issues. Study of Properties, structure and functions of various Nutraceuticals (3 examples) formulation of functional food, stability, analysis. Food as remedies, Anti-nutritional Factors present in Foods, Nutraceutical Industry and Market Information.

UNIT – 3 **(4 hrs)**

Soaps and Detergent – Introduction, Chemistry, Classification, Manufacture and Environmental aspects, Analysis of Soaps surfactants and detergents: determination of surface tension, interfacial tension, and CMC, Testing of TFM of soap, % active matter of detergents.

UNIT – 4 **(6 hrs)**

Recent developments- Spray Dried Powdered Detergents, Concept of HLB and other related terms, detersive system, micro emulsion, multiple emulsion system, nanoemulsion system. Disinfectants, Surfactant Industry and Market Information.

UNIT – 5 **(6 hrs)**

Hydraulic expelling, Solvent extraction and separation of oils and fats, Aqueous extraction, Liquid liquid extraction for deacidification, Miscella refining and double solvent refining, High pressure fat splitting, fatty acid distillation, Saponification of Oils, Soap formulation and Plodder Processing, Synthesis various anionic, cationic, nonionic and amphoterric surfactants, Formulation and Processing of Detergent Powder by combined absorption and neutralisation mode, Purification of wax, Formulation and Processing of different Skin and Hair Care Products. Production Management, Marketing.

Recommended Text Books:

1. B.K. Sharma, Industrial Chemistry, GOEL Publishing House, 2000.
2. Mohammad Farhat Ali, Bassam Ali, James Speight, Handbook of Industrial Chemistry Organic Chemicals, McGraw-Hill 2005.
3. O. P. Narula, Treatise on fats, fatty acids and oleochemicals by, Industrial Consultants (India), Vo. I & II, 1994.
4. V. V. S. Mani and A. D. Shitole, Fats, Oleochemicals and surfactants challenges in 21st Century by Oxford and IBH Publishing Co. Pvt. Ltd., 1997.
5. Robert E. C. Wildman, Handbook of Nutraceuticals and Functional Foods, CRC Press 2016.

ELECTIVE

CHE 2309

MATERIALS CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Evaluate a material in terms of its properties and device plausiblesynthetic strategies.	Analyse
C.O. 2: Suggest the applicability of a given material for a specific application.	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x	x	
C.O.2	x	x		x				x	x	

UNIT – 1 **(8 hrs)**

Chemistry of Materials. Historical perspectives – strategies for the design of new materials- a critical thinking approach. Ionic and covalent solids. Molecular and metallic solids. Amorphous and crystalline materials. Crystalline state. Structural organization of crystalline solids-theories of bonding. Crystal structures. Imperfections in crystal structures. Amorphous materials – glasses and ceramic solids. Structural organization of amorphous solids. Traditional ceramics. Synthetic high performance ceramics. Crystal structure of ceramics.

UNIT – 2 **(8 hrs)**

Metals and alloys. Structural and bonding theories of metals. Alloys -ferrous alloys – phase behavior of ferrous alloys. Behaviour of binary alloys. Intermediate compounds and intermediate phases. Nonferrous metals and alloys.

Shape memory alloys. PZT materials. Optical, electrical and magnetic properties of metallic materials.

UNIT – 3 **(4 hrs)**

Semiconductor materials- properties and types of semiconductors. Structure and Bonding of semiconductor materials. Silicon based semiconductors. II-VI (wide band gap) and IIIV (narrow band gap) compound semiconductors. Electrical, optical and magnetic properties of semiconductor materials. Preparation and properties of ZnO, ZnS, CdS, CdTe, Ga-As, In-S, Cu-In-S. Application in photovoltaic devices

UNIT – 4 **(6 hrs)**

Polymer Materials- classification and nomenclature of polymers. Methods of Polymerization. Dendritic and cascade polymers. Polymers via Click Chemistry. Properties of polymers. Plastics and elastomers. Viscoelastic behavior. Rubber like elasticity. Conducting polymers. Crystalline and amorphous polymers. Glass transition temperature and crystalline melting.

Polymer composites- polymer matrix composites.

UNIT – 5 **(6 hrs)**

Nanomaterials. Materials in the nanodomain. Zero, one and two dimensional materials. Particle size dependent change in properties of materials. Metals in the nanodomain. Gold and silver nanoparticles. Preparation and properties. Core shell structures. Semiconductor nanoparticles. Quantum dots. ZnO, ZnS, CdS and CdSe quantum dots. Electrical and optical properties. Nano domains of Carbon-fullerenes, carbon nanostructures, graphene. Energy and environmental applications.

Recommended Text Books:

10. Fahlman, B. D. Materials Chemistry, 2nd Ed., Springer, Heidelberg,2011.
11. Zallen, R. Physics of Amorphous Solids, Wiley, New York,1983.
12. Borg, R. J. and Dienes, G. J. The Physical Chemistry of Solids, Academic Press, Boston,1993.

13. Kingery, D.; Bowen, H. K.; Uhlmann, D. R. Introduction to Ceramics, 2nd Ed., Wiley, New York,1992.
14. Cowie, J. M. J. Polymers. Physics and Chemistry of Modern Materials, 3rd Ed., CRC Press, Boca Raton, 2007.
15. Kasap, S. O. Principles of Electronic Materials and Devises, Mc GrawHill,2006.

MOOC ELECTIVE

CHE 2310

BONDS AND BANDS IN SOLIDS

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe the theoretical aspects of solid state structure	Understand
C.O.2: Correlate the structural aspects to electronic properties	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x								
C.O.2	x	x								

UNIT – 1 **(6 hrs)**

One-electron Hamiltonian after B.O and SCF approx., Bonding in Hn System, n=2,3….N

UNIT – 2 **(6 hrs)**

Bloch's theorem, Energy bands, Metal, Insulator, Semi-conductors; Brillouin Zones, Different Schemes, Density of States, Extension to p-orbitals, square lattices etc

UNIT – 3 **(6 hrs)**

Peiperl's instability, Nearly Free Electron Model, Fermi Surface, Density of States, Effective Mass etc.,, Failures of MO and Band Theories, Beyond energy band , Interacting electron models and Kinetic exchange

UNIT – 4 **(6 hrs)**

Energy levels in interacting models, Excitons; Lattice, vibrations, Acoustic modes, optic modes etc.,

UNIT – 5 **(8 hrs)**

Phonon Photon interaction, thermal properties of insulators

Recommended Text Books:

1. C. Kittel, “Introduction to Solid State Physics”
2. J. M. Ziman, “Principles of the Theory of Solids”
3. N.W. Ashcroft and N.D. Mermin, “Solid State Physics”

SWAYAM

Prof. S. Ramashesha

IISc Bangalore

Semester 3

CORE/LAB

CHE 2401

PROJECT DISSERTATION

Credit 16

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Identify and hypothesise an advanced level research problem.	Create
C.O.2: Design experiments and validate the hypothesis of an advanced level research problem.	Create

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x	x	x	x	x		x	x	
C.O.2	x	x	x	x	x	x	x	x	x	

UNIT – 1

The students shall carry out research project in reputed research laboratory for the entire semester.

The students shall submit a project report on the research work carried out.

The students will have to present the results of the research project in a seminar and appear for a comprehensive viva-voce.

INTERDEPARTMENTAL ELECTIVE

CHE 2311

MOLECULAR MODELING IN CHEMISTRY

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe the basic concepts of the various theoretical models and methods.	Understand
C.O.2: Classify the different basis sets used in the computational calculations.	Understand
C.O.3: Calculate the geometry of a molecule, its IR and UV spectra, its thermodynamic and kinetic stability, and other information needed for the prediction of the reactivity.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x							x	x	
C.O.2	x							x	x	
C.O.3	x							x	x	

UNIT – 1 **(12 hrs)**

The Schrödinger Equation, The Time-Independent Schrödinger Equation, Born-Oppenheimer approximation, The Molecular Potential Energy Surface, Multiple Minima, Saddle Points, Characterization, Finding Minima, LCAO, Hartree-Fock theory, Roothan–Hall equations, Koopmans theorem, HF limit and electron correlation.

UNIT – 2 **(12 hrs)**

Basis sets, basis set approximation, Slater and Gaussian functions, contractions, polarization and diffuse functions, split-valence sets, classification of basis sets – minimal, double zeta, triple zeta, correlation-consistent sets, core-valence sets, general contractions, EMSL basis set exchange.

UNIT – 3 **(14 hrs)**

Semi empirical methods, post Hartree-Fock Method, Configuration interaction, Many-body perturbation theory, Coupled-cluster theory, Nondynamical correlation and multiconfigurational self-consistent-field (MCSCF) theory, Density Functional Theory, Hybrid QM/MM.

UNIT – 4 **(14 hrs)**

Input of molecular structure, Z-matrix construction, single point energy calculations, geometry optimizations, Electronic Energy, Vibrational frequency analysis, symmetry analysis, zero-point vibrational energies (ZPVE's), distinguishing minima from transition states, Intrinsic reaction coordinate (IRC) analysis, transition barrier and activation energy, conformational energetics, reaction energetics, enthalpy of formation, bond dissociation energy, ionization energy, isomerization energy and barrier, potential energy surface, reaction mechanism, enthalpy, entropy and free energy changes for reactions, isodesmic reactions.

UNIT – 5 **(12 hrs)**

Introduction to molecular mechanics; The Force Field Energy, The stretch energy, The bending energy, The out-of-plane bending energy, The torsional energy, The van der Waals energy, The electrostatic energy: charges and dipoles, Force Field Parameterization, Universal force fields, Advantages and Limitations of Force Field Methods, Basics of Molecular Dynamics Simulation, Generating and Analyzing a Molecular Dynamics Trajectory, Methods for Calculation of Free Energy, Application to Intermolecular Interactions and Binding Energies, Solvation Models, Combined QM/MM methods, Application of QM/MM to Enzyme.

Recommended Text Books:

1. C. J. Cramer, Essentials of Computational Chemistry: Theories and Models, 2nd ed., John Wiley & Sons, 2004.
2. F. Jensen, Introduction to Computational Chemistry, 3rd ed., Wiley, New York, 2017.
3. A. R. Leach, Molecular Modelling Principles and Applications, 2nd ed., Pearson Education Limited, 2001
4. I. N. Levine, Quantum Chemistry, 7th ed., Pearson, 2013.

INTERDEPARTMENTAL ELECTIVE

CHE 2312

SPECTROSCOPIC TECHNIQUES

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Explain the fundamentals of spectroscopy.	Understand
C.O.2: Correlate the structure of molecule with UV-Visible and IR spectral data.	Apply
C.O.3: Interpret first order NMR spectra.	Analyse
C.O.4: Determine the primary structure of peptides based on mass spectra.	Analyse
C.O.5: Examine secondary structure of peptides based on IR, NMR and mass spectral data.	Evaluate
C.O. 6: Explain the applications of X ray and microscopic techniques.	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x				x		x		
C.O.3	x	x				x		x		
C.O.4	x	x				x		x		
C.O.5	x	x				x		x		
C.O.6	x	x				x		x		

UNIT – 1 **(12 hrs)**

Different regions of electromagnetic spectrum and energy associated with a particular frequency, Types of spectroscopic techniques, Energy levels in molecules. Population of energy levels, basics of light absorption, factors affecting sensitivity, intensity and width of spectral lines, absorption characteristics, structural information based on absorption characteristics

UNIT – 2 **(12 hrs)**

UV-visible spectroscopy – Principle, allowed and forbidden transitions, chromophores, auxochromes, effect of structure on absorption characteristics

Basics of ORD and CD and emission spectroscopy.

IR spectroscopy –Principle, intra and intermolecular hydrogen bonding, effect of concentration and temperature, Fourier transform IR, group frequencies, fundamental frequencies, overtones, Fermi Resonance.

UNIT – 3 **(14 hrs)**

Experimental aspects of FT NMR, factors influencing sensitivity and resolution, Proton NMR, Chemical shift, Applications of chemical shift, spin-spin coupling, Analysis of spin systems, factors affecting coupling constants, NMR of Carbon-13, DEPT analysis and brief introduction to correlation spectroscopy (COSY, HMBC and HSQC). Brief introduction to NMR of other biologically relevant nuclei such as ^{15}N, ^{2}D and ^{31}P.

UNIT – 4 **(14 hrs)**

Mass spectrometry - high resolution mass spectrometry, soft ionization techniques, MS/MS data, application of GC-MS and LC-MS data, introduction to fragmentation modes and determination of primary structure of peptides on the basis of mass spectral data.

Problems based on combined application of various spectroscopic techniques to examine secondary structure of peptides.

UNIT – 5 **(12 hrs)**

Introduction to microscopic and X-ray techniques. Confocal microscopy, fluorescence and radioisotope labeling as diagnostic tools. Basic introduction to Electron microscopy: types, sample preparation and analysis. Powder XRD and single crystal XRD

Recommended Text Books:

1. D. L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Spectroscopy, A Guide for Students of Organic Chemistry, 3rd ed., Thomson. 2004.
2. Atta-Ur-Rahman, M. I. Choudhary, Solving Problems with NMR Specroscopy, Academic Press, New York, 1996.
3. L. D. Field, S. Sternhell, J. R. Kalman, Organic Structures from Spectra, 4th ed., Wiley, 2008.
4. R. S. Drago, Physical Methods for Chemist, Saunders, 1992.
5. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th ed., McGrawHill, 1994.
6. D. F. Taber, Organic Spectroscopic Structure Determination, A Problem Based Learning Approach, Oxford University Press, 2009.
7. H. Gunther, NMR Spectroscopy, 2nd ed., John Wiley and Sons, 1995.
8. R. M. Silverstein, G. C. Bassler, T. C. Morril, Spectroscopic identification of organic compounds, John Wiley, 1991.
9. D. H. Williams, I. Fleming, Spectroscopic Methods in Organic Chemistry, Tata McGraw Hill. 1988. 10. W. Kemp, Organic Spectroscopy, 2nd ed., ELBS-Macmillan, 1987.
10. F. Bernath, Spectra of Atoms and Molecules, 2nd ed., Oxford University Press, 2005.
11. E. B. Wilson, Jr., J. C. Decius, P. C. Cross, Molecular Vibrations: The Theory of Infrared and Raman Spectra, Dover Publications, 1980.
12. A. Weil, J. R. Bolton, Electron Paramagnetic Resonance: Elementary Theoryand Practical Applications, 2nd ed., Wiley Inter Science, John Wiley & Sons, Inc., 2007.
13. C. P. Slichter, Principles of Magnetic Resonance, 3rd ed., Springer-Verlag, 1990.
14. H. Gunther, NMR Sprectroscopy: Basic principles, Concepts, and Applications in Chemistry, 2nd ed., Wiley 1997.
15. Spectral data bases (RIO DB of AIST, for example).

Guide lines for setting up Question Papers in Theory Courses

1. The entire syllabus must be covered in the question paper.
2. Each question must be mapped to a specific C.O.
3. All the C.O.s must be reflected in the question paper.
4. The question paper may consist of questions at different cognitive levels such that, 20% of “remember” level, 40% of “understand” level and 40% of “apply and higher” level.

END

Appendix -2

Centre for Integrated Studies

Cochin University of Science and Technology

Integrated M.Sc. (Chemistry) Syllabus

2020-21

Programme Objective

The five-year Integrated M. Sc in Chemistry aims to impart a sound foundation in basic sciences with a focus on transdisciplinary subjects in order to build human resources for innovative research in Chemical Science and train competentmanpower who can take challenges in teaching and research.

Programme Outcomes

On successful completion of the five-year Integrated M. Sc. Chemistry programme, studentswill be able to

P.O.1: acquire systematic and coherent understanding of the fundamental concepts.

P.O.2: demonstrate comprehensive knowledge and understanding of both theoretical and experimental/applied chemistry in various fields.

P.O.3: design and perform the chemical synthesis and characterize the products.

P.O.4: design and execute experimental routines for detection and quantification of chemicalentities.

P.O.5: analyze the kinetics and energetics of chemical processes and infer the mechanism.P.O.6: demonstrate the basic principles of instrumental methods of analysis.

P.O.7: operate advanced instruments and related soft-wares to execute in-depth analysis ofchemical problems.

P.O.8: design and develop new molecules/processes with industrial and societal applications.

P.O.9: acquire skills for future employment in academia and industry.

P.O.10: demonstrate knowledge relevant to the regional, national and international development needs.

SEMESTER: 1

Semester Credit: 23 (Core: 23; Elective: 0) Cumulative Credit: 23

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
ENG10101	English – I	Core	2	2-1-0	50	50	100
	Language						
MAL10101	Malayalam – I	Core	2	2-1-0	50	50	100
HIN10101	Hindi – I						
FLG10101	German – I						
CHE10101	Atomic Structure and Chemical Bonding	Core	3	3-1-0	50	50	100
PHY 10101	Mechanics	Core	3	3-1-0	50	50	100
BIO 10101	General Biology	Core	3	3-1-0	50	50	100
MAM 10101	Calculus-I	Core	4	4-1-0	50	50	100
CHE10102	Inorganic Quantitative Analysis Lab	Core	2	0-0-6	100	-	100
PHY 10102	Physics Lab (Mechanics)	Core	2	0-0-6	100	-	100
BIO 10102	General Biology Lab	Core	2	0-0-6	100	-	100

SEMESTER: 2

Semester Credit: 23 (Core: 23; Elective: 0) Cumulative Credit: 46

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
ENG10201	English – II	Core	2	2-1-0	50	50	100
	Language						
MAL10201	Malayalam – II	Core	2	2-1-0	50	50	100
HIN10201	Hindi – II						
FLG10201	German – II						
CHE10201	Periodicity, Nuclear Chemistry, Metallurgy and Acid Base Chemistry	Core	3	3-1-0	50	50	100
PHY 10201	Waves and Optics	Core	3	3-1-0	50	50	100
BIO 10201	Biochemistry	Core	3	3-1-0	50	50	100
MAM 10201	Linear Algebra, Group Theory	Core	4	4-1-0	50	50	100
CHE10202	Inorganic Qualitative Analysis Lab	Core	2	0-0-6	100	-	100
PHY 10202	Physics Lab (Waves and Optics)	Core	2	0-0-6	100	-	100
BIO 10202	Biochemistry Lab	Core	2	0-0-6	100	-	100

SEMESTER: 3

Semester Credit: 25 (Core: 25; Elective: 0) Cumulative Credit: 71

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10301	Introductory Organic Chemistry	Core	3	3-1-0	50	50	100
PHY 10301	Electricity and Magnetism-I	Core	3	3-1-0	50	50	100
BIO 10301	Cell Biology	Core	3	3-1-0	50	50	100
MAM 10301	Calculus-II	Core	4	4-1-0	50	50	100
MAM 10302	Mathematical Methods-I	Core	4	4-1-0	50	50	100
EVS10301	Environmental Science	Core	2	2-1-0	50	50	100
CHE10302	Organic Qualitative Analysis Lab	Core	2	0-0-6	100	-	100
PHY 10302	Physics Lab (Electricity and Magnetism)	Core	2	0-0-6	100	-	100
BIO 10302	Cell Biology Lab	Core	2	0-0-6	100	-	100

SEMESTER: 4

Semester Credit: 25 (Core: 25; Elective: 0) Cumulative Credit: 96

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE10401	Introductory Physical Chemistry	Core	3	3-1-0	50	50	100
PHY 10401	Quantum Physics and Relativity	Core	3	3-1-0	50	50	100
BIO 10401	Molecular Biology and Genetics	Core	3	3-1-0	50	50	100
MAM 10401	Mathematical Methods-II	Core	4	4-1-0	50	50	100
STA 10401	Probability and Statistics	Core	4	4-1-0	50	50	100
COM10401	Basic Computer Science	Core	2	2-1-0	50	50	100
CHE10402	Physical Chemistry Lab	Core	2	0-0-6	100	-	100
PHY 10402	Physics Lab (Modern Physics)	Core	2	0-0-6	100	-	100
BIO 10402	Molecular Biology and Genetics Lab	Core	2	0-0-6	100	-	100

SEMESTER: 5

Semester Credit: 20 (Core: 20; Elective: 0) Cumulative Credit:116

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10501	Analytical Chemistry-I (Analytical Techniques, Instrumental Methods, Molecular Spectroscopy)	Core	3	3-1-0	50	50	100
CHE 10502	Inorganic Chemistry-I (Chemistry of Main Group Elements)	Core	3	3-1-0	50	50	100
CHE 10503	Organic Chemistry-I (Functional Group Chemistry)	Core	3	3-1-0	50	50	100
CHE 10504	Physical Chemistry-I (Equilibrium Thermodynamics)	Core	3	3-1-0	50	50	100
CHE 10505	Mathematics for Chemists	Core	2	2-1-0	50	50	100
CHE 10506	Inorganic Chemistry Lab	Core	2	0-0-6	100	-	100
CHE 10507	Organic Chemistry Lab	Core	2	0-0-6	100	-	100
CHE 10508	Open Ended Lab-I	Core	2	0-0-6	100	-	100

SEMESTER: 6

Semester Credit: 20 (Core: 20; Elective: 0) Cumulative Credit:136

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10601	Inorganic Chemistry-II (Coordination Chemistry)	Core	3	3-1-0	50	50	100
CHE 10602	Organic Chemistry-II (Structure, Stereochemistry and Conformational Analysis)	Core	3	3-1-0	50	50	100
CHE 10603	Physical Chemistry-II (Electrochemistry, Solid State and Liquid State)	Core	3	3-1-0	50	50	100
CHE 10604	Industrial Chemistry	Core	3	3-1-0	50	50	100
CHE 10605	Computer Programming and Numerical Methods	Core	2	2-1-0	50	50	100
CHE 10606	Advanced Physical Chemistry Lab-I	Core	2	0-0-6	100	-	100
CHE 10607	Industrial Chemistry Lab	Core	2	0-0-6	100	-	100
CHE 10608	Open Ended Lab-II	Core	2	0-0-6	100	-	100

SEMESTER: 7

Semester Credit: 21 (Core: 16; Elective: 5) Cumulative Credit:157

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10701	Inorganic Chemistry -III (Concepts and Developments)	Core	3	3-1-0	50	50	100
CHE 10702	Organic Chemistry-III (Reactivity and Mechanisms)	Core	4	4-1-0	50	50	100
CHE 10703	Theoretical Chemistry-I (Quantum Chemistry)	Core	3	3-1-0	50	50	100
CHE 10704	Theoretical Chemistry-II (Group Theory and Spectroscopy)	Core	4	4-1-0	50	50	100
CHE 10705	Advanced Chemical Synthesis and Separation Lab	Core	2	0-0-6	100	-	100
CHE 10706	Open Ended Lab-III	Core[c]	-	-	0-0-6	-	-
CHE 10707	Supramolecular Chemistry	Elective	3	2-1-0	50	50	100
CHE 10708	Green Chemistry	Elective	3	2-1-0	50	50	100
CHE 10709	Polymer Chemistry	Elective	3	2-1-0	50	50	100
CHE 10710	Bonds and Bands in Solids	Elective[a]	2	2-1-0	50	50	100
CHE 10711	Professional and Career Development in Chemistry	Audit [b]	-	2-0-0	-	-	-

SEMESTER: 8

Semester Credit: 20 (Core: 16; Elective: 4) Cumulative Credit:177

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10801	Inorganic Chemistry-IV (Chemistry of d- and f-Block Elements)	Core	3	3-1-0	50	50	100
CHE 10802	Organic Chemistry -IV (Reactions, Reagents and Synthesis)	Core	4	4-1-0	50	50	100
CHE 10803	Organic Chemistry -V (Spectroscopy of Organic Compounds)	Core	2	2-1-0	50	50	100
CHE 10804	Physical Chemistry-III (Statistical and Nonequilibrium Thermodynamics)	Core	3	3-1-0	50	50	100
CHE 10805	Theoretical Chemistry-III (Chemical Bonding and Computational Chemistry)	Core	2	1-1-3	50	50	100
CHE 10806	Advanced Physical Chemistry Lab-II	Core	2	0-0-6	100	-	100
CHE 10807	Open Ended Lab-IV	Core[c]	-	0-0-6	-	-	-
CHE 10808	Bioanalytical Chemistry	Elective	2	2-1-0	50	50	100
CHE 10809	Advanced Photochemistry	Elective	2	2-1-0	50	50	100
CHE 10810	Theory of Orbital Interactions in Chemistry	Elective	2	1-1-3	50	50	100

SEMESTER: 9

Semester Credit: 23(Core: 17; Elective: 6) Cumulative Credit:198

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 10901	Analytical Chemistry-II (Advanced Analytical Techniques and Instrumental Methods)	Core	4	4-1-0	50	50	100
CHE 10902	Inorganic Chemistry -V (Organometallic and Bioinorganic Chemistry)	Core	3	3-1-0	50	50	100
CHE 10903	Organic Chemistry-VI (Chemistry of Natural Products)	Core	3	3-1-0	50	50	100
CHE 10904	Physical Chemistry-IV (Chemical Kinetics, Reaction Dynamics, Catalysis and Surface Chemistry)	Core	3	3-1-0	50	50	100
CHE 10905	Physical Chemistry-V (Advanced Electrochemistry)	Core	2	2-1-0	50	50	100
CHE 10906	Open Ended Lab-V	Core	2	0-0-6	100	-	100
CHE 10907	Oleochemicals, Nutraceuticals, Surfactant Technology	Elective	2	2-1-0	50	50	100
CHE 10908	Materials Chemistry	Elective	2	2-1-0	50	50	100
CHE 10909	Chemical Crystallography	Elective[a]	4	4-1-0	50	50	100

SEMESTER: 10

Semester Credit: 16 (Core: 16; Elective: 0) Cumulative Credit : 216

Course Code	Course Name	Course Type	Credits	L-T-P	CE	ESE	Total Marks
CHE 11001	Project Dissertation and Viva Voce	Core	16	-	-	300	300

a- MOOC Course
b- Value Added Course
c- Evaluation in third semester
L-T-P ≡ Lecture-Tutorial-Practical Hours
CE ≡ Continuous Evaluation; ESE ≡ End Semester Evaluation

CORE

CHE 10101

ATOMIC STRUCTURE AND CHEMICAL BONDING

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Describe the major discoveries that led to the foundation of quantum mechanics	Understand
C.O. 2: Correlate the concepts of quantum mechanics toatomic structure	Apply
C.O. 3: Correlate the concepts of atomic structure toproperties of atoms	Analyse
C.O. 4: Apply the concept of atomic orbitals to buildmolecular orbitals	Apply
C.O. 5: Evaluate the structure and bonding of any molecule	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x									
C.O.2	x	x								
C.O.3	x	x								
C.O.4	x	x								
C.O.5	x	x								

UNIT – 1 **(10 hrs)**

Black body radiation, Planck’s law, Hydrogen spectrum, Bohr’s theory, its limitations, Photoelectric effect, Double slit experiment, Heisenberg'suncertainty principle and its significance, Wave-Particle duality, de Broglieequation.

Limitations of classical mechanics in describing the properties of microscopic particles.

UNIT – 2 **(10 hrs)**

Schrödinger's wave equation, significance of ψ and ψ^2, Quantum numbers and their significance. Sign of wave functions. Radial and angular wave functions. Radial and angular distribution curves. Shapes of s, p, d and f orbitals. Contour boundary and probabilitydiagrams.

UNIT – 3 **(8hrs)**

Quantization, Electronic Transitions, Quantum Theory, Atomic Energy States, Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number. Electronic energy level diagram and electronic configurations of hydrogen-like and polyelectronic atoms and ions. Excited states.

UNIT – 4 **(10 hrs)**

Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Lande equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Solvation energy, Covalent bond, Lewis structure, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths, Ionic character in covalent compounds: Bond moment and dipole moment.

UNIT – 5 **(10 hrs)**

Valence Bond theory, Hybridization, equivalent and non-equivalent hybrid orbitals. Bent's rule, Resonance and resonance energy, Molecular orbital theory. bonding, non- bonding, antibonding molecular orbitals (concept only) elementary pictorial approach of homo- and hetero-diatomic molecules H_2, B_2, C_2, O_2, N_2, CO, NO and CO_2, H_2O etc. molecular orbitals, sigma and pi bonds, multiple bonding, Concept of Bond order, bond length, bond strength, bond energy, Formal charge, Molecular Electron Configurations, Metallic Bond: Qualitative idea of valence bond and band theories. Semiconductors and insulators, Van der Waal's forces, ion-dipole, dipole–dipole interactions, London forces, Hydrogen bonding; Effect of chemical forces on physical properties.

Recommended Text Books:

1. Lee, J.D. Concise Inorganic Chemistry, 5th Ed., John Wiley & Sons, 1999.
2. Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of Inorganic Chemistry, 3rd Ed., Oxford, 1994.
3. Atkins, P.W. and Paula, J. Physical Chemistry, 8th Ed., Oxford Press, 2006.
4. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, 2nd Ed., ACS Publications, 2002.
5. Huheey, J. E., Keiter, E. A. and Keiter, R. L. Inorganic Chemistry, Principle and structure and reactivity, 4th Ed., Harper Collins College Publishers, New York,1993.
6. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4th Ed., W.H. Freeman & Company, 2006.
7. Housecroft, C. and Sharpe, G., Inorganic Chemistry, 4th Ed., Pearson, 2012.
8. Levine, I. N. Physical Chemistry, 6th Ed., McGraw-Hill Education, 2008.

CORE/LAB

CHE 10102

QUANTITATIVE ANALYSIS LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Develop basic concepts of quantitative volumetric analysis	Understand
C.O. 2: Estimate the amount of a given substance byacidimetry, alkalimetry and permanganometry	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1 **(96 hrs)**

I. Acidimetry and Alkalimetry

1. Strong acid- Strong base

2. Strong base –Weak acid

3. Strong acid-Weak base

4. Estimation of hardness of water

II. Redox Titration (Permanganometry)

1. Estimation of Oxalic acid

2. Estimation of Mohr's salt

3. Estimation of Ferrous iron

4. Estimation of Manganese dioxide in pyrolusite

Recommended Text Books:

1. Vogel's Textbook of Quantitative Chemical Analysis, 6th Ed., Pearson Education Ltd.

2. Laboratory Manual, CHE 10102, Department of Applied Chemistry, CUSAT

CORE

CHE 10201

PERIODICITY, NUCLEAR CHEMISTRY, ACID BASE CHEMISTRY AND METALLURGY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Correlate the physical and chemical properties of elements based on their periodic classification	Analyse
C.O.2: Analyse the properties, stability, mode of decay and kinetics of a given nucleus/nuclear process	Apply
C.O.3. Describe the radioactivity phenomena and its applications	Understand
C.O.4: Compare the strength of various acids and bases	Apply
C.O.5: Explain the occurrence of minerals and metallurgical principles for isolation and purification	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x								
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					
C.O.5	x	x			x					

UNIT – 1 **(10 hrs)**

Atomic weights, Development of periodic law, The modern periodic table, Basis of periodic classification, orbital types and periodic table, Commonality in electronic configurations, Atomic sizes, ionization energy, Electron negativity, Electron Affinity, Polarizability and polarizing power, Relative orbital energies and overlap, Trends associated with properties – Physical and chemical, Anomalies in periodic properties. Predicting Chemistry of super heavy elements.

UNIT – 2 **(14 hrs)**

Nuclear radius, Nuclear Forces, Nuclear Spin, Magnetic dipole moment, Elementary Particles, Binding Energy, Nuclear models – Shell model- magic number, periodicity in nuclear properties, Liquid drop model – fission and fusion, Nuclear Stability, Exchange theory, n/p ratio, Nuclear Radiations, Nuclear reactions, Types of nuclear reactions, Decay Kinetics, Half-life, Radioactive disintegration series. Fission: Fission products and Fission yield curve, Fission energy, theory of nuclear fission, nuclear reactor, breeder reactor
- nuclear reactors in India. Fusion reactions, hydrogen bomb and energy of sun.

UNIT – 3 **(8hrs)**

Transuranium elements: Synthesis, separation and properties of transuranium elements.Radioisotopes:Co-precipitation,ion-exchange,solventextraction as a tracer, Synthesis of labeled compounds (any two), isotopic dilution and radiopharmaceuticals. Neutron activation analysis, Principles of determination of age of rocks and minerals, radio carbon dating principles, Isotope dilution and neutron activation analysis.

UNIT – 4 **(8 hrs)**

Acid Base concepts, Bronsted-Lowry definition, Lux Flood Definition, Solvent system definition, Lewis Definition, Usanovich Definition, Generalized concept, Measures of acid base concept, Acid Base anomalies, Pearson's HSABconcept, acid-base strength and hardness and softness, Symbiosis, theoretical basis of hardness and softness, electronegativity and hardness.

UNIT – 5 **(8 hrs)**

Occurrence of metals based on standard electrode potential, methods of concentration of ores, reduction to free metal, electrometallurgy, hydrometallurgy, and synthesis of ultrapure elements. Refining of metals, electrolytic, ion exchange, zone refining, vapour phase refining and oxidative refining. Thermodynamics of the oxidation of metals to metaloxides- Ellingham diagrams. Extractive metallurgy of U, Th, Ti.

Recommended Text Books:

1. Mingos, D. M. P., Essential trends in inorganic chemistry, Oxford University press 1998.
2. Wulfsberg, G., Inorganic Chemistry, VIVA,2002.
3. Greenwood, N. N., Earnshaw, A., Chemistry of Elements, Maxwell Macmillan International Edition, Pergamon Press, 1989.
4. Cotton, F.A., Wilkinson, G, Advanced Inorganic Chemistry. Wiley-VCH,1999.
5. Huheey, J. E., Keiter, E. A., Kieter, R. L., Medhi, O. K., Inorganic Chemistry Principles Structure and Reactivity, Pearson Education, 4th edition,2009.
6. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4th Ed.,
7. W.H. Freeman & Company,2006.
8. Douglas, B.E. and Mc Daniel, D.H., Concepts & Models of Inorganic Chemistry, 3rd Ed., Oxford, 1994.
9. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed., Pearson, 2014.
10. Sharma, B. K., Industrial Chemistry (including Chemical Engineering), GOEL Publishing House,1997.
11. Arnikar, H. J., Essentials of Nuclear Chemistry, Wiley Eastern Ltd., New Delhi, 1982.

CORE/LAB

CHE 10202

INORGANIC QUALITATIVE ANALYSIS LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Develop basic concepts of inorganic qualitative analysis	Understand
C.O. 2: Identify acid radicals and basic radicals from a given sample mixture	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1 **(96 hrs)**

Systematic qualitative analysis of mixtures containing two acid and two basic radicals from the list given below by semi micro method

Pb^{2+}, Cu^{2+}, Bi^{2+}, Cd^{2+}, Fe^{2+}, Fe^{3+}, Al^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mg^{2+}, NH_4^+; CO_3^{2-}, SO^{2-}, NO^-, F^-, Cl^-, $C\,O^{2-}$, $CH\,COO^-$, PO^{3-}, CrO^{2-}

Recommended Text Books:

1. A.I. Vogel, A Text Book of Qualitative Inorganic Analysis, Longman,1966.
2. Laboratory Manual, CHE 10202, Department of Applied Chemistry,CUSAT

CORE

CHE 10301

INTRODUCTORY ORGANIC CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Assign the nomenclature of simple organic molecules following IUPAC rules	Apply
C.O.2: Illustrate different bonding models to predict the three dimensional structure of molecules.	Analyse
C.O.3: Apply the concepts of isomerism and analyse the conformation and configuration of organic molecules.	Analyse
C.O.4: Describe the different types of organic reactions	Understand
C.O.5: Develop an insight into the importance of organic chemistry in life	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x								
C.O.2	x	x								
C.O.3	x	x								
C.O.4	x	x								
C.O.5	x	x								

UNIT – 1 **(6 hrs)**

Nomenclature of organic compounds. Rules of IUPAC system of nomenclature of common organic compounds – alkanes, alkenes, alkynes, cycloalkanes, bicycloalkanes, alkyl halides, alcohols and phenols. Aldehydes, ketones, carboxylic acids and its derivatives, amines, nitro compounds, heterocyclic compounds.

UNIT – 2 **(10 hrs)**

Structure and Models of bonding: Study of Lewis Structures, Formal Charge, VSEPR, Hybridization, localised σ and π bonds, polar covalent bonding, Bond dipoles, molecular dipoles and quadrupoles, polarizability, Resonance, Bond Lengths and Bond energy.

UNIT – 3 **(10 hrs)**

Stereochemistry: Concept of Configuration, Classification of Stereoisomers, Optical isomerism, Chirality, Wedge formula, Fischer projection, Newman projection, perspective formula. Relative and absolute configurations, sequence rules, D & L, R & S systems of nomenclature. Enantiomers, meso form, diastereoisomers, epimers, anomers. Geometrical Isomerism: E-Z notation - determination of configuration.

Conformational analysis: Strain in molecules, acyclic molecules, cyclohexane, substituted cyclohexanes- A values.

UNIT – 4 **(12 hrs)**

Basic introduction to Organic reactions: Classification and an overview of organic reactions. Electron pushing diagrams. Basics of reaction coordinate diagrams, intermediates, transitions states, exothermic and endothermic reactions,activation energy, rates of reactions and rate determining step. Hammond's postulate. Nucleophilic substitutions - S_N1, S_N2, substitutions on aromatic carbon,Addition reactions - polar and non-polar addition - addition of Bromine and hydrogen halides to double bonds - Markownikoff's rule and peroxide effect., Elimination - E1, E2, E1cb, pyrolytic elimination. Basic introduction to rearrangements and Pericyclic Reactions.

UNIT – 5 **(10 hrs)**

Organic Chemistry in life: Natural products (structure and classification) – Terpenes, Steroids and alkaloids. Biomolecules (structure and function):

carbohydrates, amino acids, proteins and nucleic acids. Pharmaceuticals and Drugs, Dyes and Chemistry of Vision. Introduction to polymer science – Monomers and Polymerisaton. Mechanisms of Radical and condensation polymersiations.

Recommended Text Books:

1. Clayden J., Greeves, N. Warren, S., Organic Chemistry (2 Ed), Oxford University Press, 2001.
2. Bruice, P.Y. Organic Chemistry, 7th Ed., Prentice Hall Inc., 2013.
3. Morrison, R.T. Boyd, R.N. and Bhattacharjee, S.K. Organic Chemistry, 6th Ed., Pearson Education Inc., 2014.
4. McMurry, J. Organic Chemistry, 5th Edition, Brooks/Cole, 2000.
5. March, J., Smith, D., March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 7th Ed., Wiley, 2013
6. Carroll, F.A. Perspectives on Structure and Mechanism in Organic Chemistry, 2nd Ed., Wiley, 2010.

CORE/LAB

CHE 10302

ORGANIC QUALITATIVE ANALYSIS LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Identify the functional group(s) present in a given organic compound	Understand
C.O.2: Categorize the unknown organic compound based on functional groupanalysis and prepare the corresponding derivative	Analysis

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1 **(96 hrs)**

Identification of simple organic compounds

Preparation of derivatives

Recommended Text Books:

1. Pavia, D.L. Lampman, G.M. Kriz, G.S. and Engel, R.G. Introduction to Organic Laboratory Techniques: A small scale Approach, 2nd Ed., 2007.
2. Dey, B.B. Sitaraman, M.V. and Govindachari, T.V. Laboratory Manual of Organic Chemistry, 3rd Ed., Viswanathan, 1957.
3. Furniss, B.S. Hannaford, A.J. Smith, P.WG. Tatchell, A.R. Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Longman, 1989.

4. Mann, F.G. Saunders, B.C. Practical Organic Chemistry, 4th Ed., Pearson Education India, 2009.
5. Clark, H.T. A handbook of organic analysis, Longman, 1966.
6. Laboratory Manual, CHE 10302, Department of Applied Chemistry, CUSAT

CORE

CHE 10401

INTRODUCTORY PHYSICAL CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Differentiate the properties of real gases from those of a perfect gas, and construct an equation of state that describes their properties.	Apply
C.O. 2: Predict changes in thermodynamic parameters during a process and predict the spontaneity.	Apply
C.O. 3: Apply the laws of chemical kinetics and photochemistry to calculate rate/ rate constants/quantum yield of different types of reactions.	Apply
C.O. 4: Understand the details of the structure of solid surfaces and the extent to which a surface is covered and the variation of the extent of coverage with the pressure and temperature	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X	X			X					
C.O.2	X	X			X					
C.O.3	X	X			X					
C.O.4	X	X			X					

UNIT – 1 **(8 hrs)**

Real gases- Deviation from ideal behavior- Compressibility factor, Van der Waals equation, Virial equation, PV isotherms, Continuity of states, Law of corresponding states, Critical phenomena and critical constants.

UNIT – 2 **(10 hrs)**

State functions, Reversible and irreversible processes, Isothermal and adiabatic processes, First, second and third laws of thermodynamics, Concepts of work, heat, Internal energy, enthalpy, Heat capacity, entropy, Gibbs energy, Helmholtz energy- Changes during isothermal and adiabatic reversible and irreversible processes. Joule Thomson effect- Inversion temperature,Application of J.T effect - Liquefaction of gases.

Entropy and free energy as criteria for spontaneity and equilibrium. Nernst Heat theorem and Unattainability of absolute zero.

UNIT – 3 **(6 hrs)**

Theories of acids and bases- Arrhenius Theory, Lewis theory and Bronsted Theory, Hard and soft acids, pH, PK_a, PK_b, Ionic product of water, Common ion effect, Solubility product, Acid strength, Degree of hydrolysis of salts, Buffer solutions, Mechanism of buffer action, Henderson equation.

UNIT – 4 **(12 hrs)**

Rate laws, Order and molecularity, Zero, first, second and third order reactions- Integration of rate laws, Half-life period, Temperature dependence of rate constant- Arrhenius equation

Photochemistry- Photochemical laws, Beer Lambert Law, Quantum yield, Jablonski Diagram -Photophysical and photochemical processes, Fluorescence, Phosphorescence-, Chemiluminescence, Bioluminescence, Photosensitisation, Photosynthesis.

UNIT – 5 **(12 hrs)**

Adsorption- Physisorption and chemisorption, Adsorption 16 Isotherms- Langmuir, Freundlich and BET isotherms (Qualitative approach), Application of isotherms for surface area determination, Catalysis- homogeneous and heterogeneous (introduction) Enzyme catalysis- Michael Menton equation.

Colloids- Lyophilic and Lyophobic colloids, Preparation of colloids, Kinetic, optical and electrical properties, Electrical double layer Models for doublelayer: Heimboltz, Gouy Champman and Stern, Zeta potential. Stability of colloids, Protective colloids- Gold number, Flocculation, Hardy Schulze rule, Surfactants, micelles, Critical miscelle concentration, Factors affecting CMC Reverse miscelle, Donnan membrane equilibrium, Dorn effect, Sedimentation potential and streaming potential, Emulsions, Gels, Sols.

Recommended Text Books:

1. Peter Atkins and Julio de Paula, Physical Chemistry, Oxford University Press, 8^{th} and 10^{th} Edn, 2017.
2. D.A McQuarrie, J.D Simon, Molecular Thermodynamics, Viva Student Edn. 2010.
3. I.N Levine, Physical Chemistry, McGraw Hill, Indian Edn, 2011.
4. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York.
5. K. J. Laidler, Chemical-Kinetics, McGraw Hill, New York.

CORE/LAB

CHE 10402

PHYSICAL CHEMISTRY LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Verify the concepts and laws in physical chemistry	Evaluate
C.O.1: Execute and perform experiments based on pH metry, potentiometry, conductometry and colorimetry to quantify andobtain other physical properties of the chemical species	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1 **(96 hrs)**

1. pH METRY

   Strong acid X strong base, Strong acid X weak base, Weak acid X Strong base

2. POTENTIOMETRY

   Strong acid X strong base, Strong acid X weak base, Weak acid X Strong base, $KMnO_4$ X Fe^{2+}

3. CONDUCTOMETRY

   Strong acid X strong base, Strong acid X weak base, Weak acid X Strong base

4. COLORIMTERY

   Estimation of iron, chromium, nickel, Manganese, Copper, phosphate in soft drinks

Recommended Text Books:

1. Gurtu, J. N., Gurtu, A., Advanced Physical Chemistry

Experiments, 6th Ed.,Pragati Prakashan,2014.

2. Yadav, J. B., Advanced Practical Physical Chemistry, 36th Ed., KrishnaPrakashan, 2016.

3. Laboratory Manual, CHE 10402, Department of Applied Chemistry, CUSAT

CORE

CHE 10501

ANLYTICAL CHEMISTRY-I
(ANALYTICAL TECHNIQUES, INSTRUMENTAL METHODS, MOLECULAR SPECTROSCOPY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Perform various statistical evaluation of experimental data	Analyse
C.O. 2: Explain the theory, instrumentation and applications of various chromatographic, spectroscopic, thermal and surface analytical methods	Apply
C.O. 3: Predict the type of spectroscopic/chromatographic method for the analysis of the given compound/mixture	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X									
C.O.2	X	X								
C.O.3	X	X	X							

UNIT – 1 **(6 hrs)**

Significant figures, Accuracy, Precision, Error, Types of errors- Determinate and Indeterminate errors, Distribution of random errors, Mathematical Expression for error- Absolute and Relative error, Methods to reduce error, Statistical tools for expressing precision- Standard deviation, Relative standard deviation, Variance, Comparison of results- Students t test, f test, Criteria for rejecting a value-Q test, Confidence interval, Correlation and Regression, Linear regression analysis

UNIT – 2 **(10 hrs)**

Chromatography-classification-column, paper, thin layer chromatography, selection of mobile and stationary phase, Theory and instrumentation of HPLC, LC-MS, GC, GC-MS, ion exchange chromatography, gel permeation chromatography, supercritical fluid chromatography and size exclusion chromatography, Important applications of chromatographic techniques

Solvent extraction and Solid phase extraction

Distribution law-Liquid-liquid extractions, synergistic extraction. Counter current extraction, super critical fluids, Electrophoresis- theory and applications.

UNIT – 3 **(12 hrs)**

Introduction to spectroscopy, spectroscopy and its importance in chemistry, interaction of electromagnetic radiation with matter, Difference between atomic and molecular spectra. Energy levels in molecules, different types of spectroscopic techniques, Basic instrumentation of spectrometers, optical systems used in spectroscopy – Sources, Filters, Monochromators, Detectors, Single and Double beam optics, Signal to noise ratio, bandwidth and band pass.

Instrumentation of NMR, FT IR, UV-Visible, Laser Raman spectroscopy and fluorescence spectroscopy

UNIT – 4 **(10 hrs)**

Atomic absorption spectroscopy – Absorption of radiant energy by atoms, Instrumentation, Interferences in AAS, Analytical applications of AAS.

Atomic Emission spectroscopy – Principle – Types – Flame atomic emission spectroscopy, Flame photometry, ICP-AES

Instrumentation and applications of ICP-AES

UNIT – 5 **(10 hrs)**

Introduction to surface characterisation techniques-SEM, AFM, TEM, XRD

Principle and applications of SEM, TEM, AFM and XRD

Introduction to thermal methods of analysis-TG, DTA and DSC

Recommended Text Books:

1. D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8th Edn., Saunders College Pub., 2007.
2. J.H. Kennedy, Analytical Chemistry: Principles, Saunders College Pub., 1990.
3. G.H. Jeffery, J. Bassett, J. Mendham, R.C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Edn., John Wiley& sons,1989.
4. G.D. Christian, J.E. O'Reilly, Instrumental Analysis, Allyn & Bacon, 1986.
5. F.W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, Blackwell Science, 2000.
6. Contemporary Instrumental Analysis, Kenneth A. Rubinson, Judith F. Rubinson, Prentice Hall, New Jersey, 2000.
7. Wilson & Wilson's, Comprehensive Analytical Chemistry, Volume 47, Modern Instrumental Analysis, Edited by S. Ahuja, N. Jespersen, Reed Elsevier India Private Ltd., Noida, 2006.
8. Journal of Chromatography Library, Volume 3, Liquid Column Chromatography-A Survey of Modern Techniques and Applications, Edited by Z. Deyl, K. Macek, J. Janak, Elsevier Scientific Publishing Company, Amsterdam, 1975.
9. Gas Chromatography, John Willett, John Wiley & Sons, Singapore, 1991.
10. Fundamentals of Analytical Chemistry, Doughlas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch, 9th Ed., Cengage Learning, 2014.

CORE

CHE 10502

INORGANIC CHEMISTRY – I

(CHEMISTRY OF MAIN GROUP ELEMENTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Describe the general periodic behaviour and occurrence of the main group elements	Understand
C.O. 2: Interpret the types of bonding based on the electronic configuration	Apply
C.O. 3: Explain the reactivity and physicochemical properties based on the type of bonding	Analyse
C.O. 4: Compare the structure, bonding and reactivity of the main group elements with the related organic compounds and transition metal complexes	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					

UNIT – 1 **(12hrs)**

s- Block elements- Hydrogen, Hydrogen Bonding, Hydrates, Hydrogen ions, acids and bases,

Group 1 elements - General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Flame colors and spectra, Color of compounds, Alkali metals in liquid ammonia and other solvents, Oxides, Hydroxides, hydrides, alkoxides, amido complexes, Ionic salts and M^+ ions in solution, Alkali metal complexes, Organolithium compounds.

Group 2 elements – General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Elemental Beryllium, Binary Compounds, Coordination compounds with oxygen and nitrogen ligand, organoberyllium compounds, Compounds of Magnesium, calcium, strontium-, oxides, halides, hydrides, carbides, ionic salts and complexes, alkoxides. Grignard reagents – preparation and properties

UNIT – 2 **(12 hrs)**

p- Block elements – Group 13 elements- General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, oxides, halides, Complex Compounds, Chemistry of oxidation states I and II, Boranes-Preparation, Classifications, Structure and Bonding, Tetrahydroborate ion, Boron Halides, Boron – Nitrogen Compounds, Boron – Oxygen Compounds.

Organometallic compounds of Al Group 14 elements – General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Carbon- Properties, Allotropes, Carbon Halides, Carbon Oxides, Compounds with C-N bond, C-S bond, Carbon compounds as ligands. Oxygencompounds of Silicon, Organo compounds, Silanes and Silenes, Organometallic compounds of Si and Sn. Inorganic Polymers,

UNIT – 3 **(8 hrs)**

Group 15 elements - General Behavior, Occurrence and abundance, Group trends and stereochemistry, Electronic Configuration and types of bonding, Active Nitrogen, Nitrogen fixation natural and artificial, Nitrogen compounds-Nitrides, Ammonia, Hydrazine, Oxides of Nitrogen, Oxo acids and anions, Halogen Compounds, nitrogen compounds as ligands, Halides of

Phosphorous, Oxides of Phosphorous, Sulfides and other chalcogenides of phosphorous, Phosphonium, Phosphorous – Nitrogen Compounds, Phosphorus-nitrogen compounds: Phosphazenes and poly phosphazenes. Organic compounds of Phosphorous, Compounds with element-element bonds, Oxo anions of Phosphorous, Phosphate in bio systems, Phosphorous compounds as ligands, Compounds of Ar, Sb and Bi.

UNIT – 4 **(8 hrs)**

Group 16 elements - General Behavior, Occurrence and abundance,Electronic Configuration and types of bonding, Group trends and stereochemistry, Types of oxides, Chemical properties of Dioxygen, Singlet oxygen, ozone, Peroxo compounds, Superoxide, Halo compounds, Oxygen compounds as ligands, Sulfanes, polysulfides, Sulphur-Nitrogen Compounds, Tetrasulphur tetranitride, disulphur dinitride and polythiazyl. SxNy compounds. S-N cations and anions. Sulphur-phosphorus compounds: Molecular sulphides such as P_4S_3, P_4S_7, P_4S_9 and P_4S_{10}. Halogen compounds of sulphur, Oxides, oxohalides and oxo acids of Sulphur, Sulphur compounds as ligands.

UNIT – 5 **(8 hrs)**

Group 17 elements- General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Halogen bonding, Preparation, C-T complexes of Halogen, Halides, Molecular halides, Halides and halogen compounds as ligands, Oxides and oxo acids, Interhalogen and poly halogen compounds, Oxohalogen fluorides. Group 18 elements - General Behavior, Occurrence and abundance, Electronic Configuration and types of bonding, Halogen compounds.

Recommended Text Books:

1. Mingos, D. M. P., Essential Trends in Inorganic Chemistry, Oxford University Press 1998.

2. Wulfsberg G., Inorganic Chemistry, VIVA, 2002.
3. Greenwood, N. N., Earnshaw, A., Chemistry of the Elements, Maxwell Macmillan International Edition, Pergamon Press, 1989.
4. Cotton, F.A., Wilkinson, G, Advanced Inorganic Chemistry. Wiley-VCH, 1999
5. Huheey, J. E., Keiter, E. A., Kieter, R. L., Medhi, O. K., Inorganic Chemistry Principles Structure and Reactivity, Pearson Education, 4th edition, 2009.
6. Lee, J. D., A New Concise Inorganic Chemistry, ELBS, 1998

CORE

CHE 10503

ORGANIC CHEMISTRY-I
(FUNCTIONAL GROUP CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Correlate structure of organic compounds with their properties	Apply
C.O. 2: Describe the synthesis and reactions of different classes of organic compounds	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x									
C.O.2			x				x	x		

UNIT – 1 **(8 hrs)**

Alkyl and aryl halides - Classification, physical properties, preparation methods, reactions.

UNIT – 2 **(10 hrs)**

Alcohols, phenol and ethers - Classification, physical properties, preparation methods, reactions – with hydrogen halide, order of reactivity of 1^o, 2^o and 3^o alcohols, with PCl_3, dehydration, with active metals, ester formation, formation of alkyl sulfonates, oxidation – primary, secondary and tertiary alcohols, chemoselective oxidants for alcohols – Oppenauer's oxidation, Moffatt-Pfitzner oxidation, Des-Martin oxidation, Alcohols as acids and bases. Ascent and decent in alcohol series Dihydric alcohols: Oxidative cleavage– Lead tetra acetate, Periodic acid- Pinacol - Pinacolone rearrangement –mechanism.

Phenols - Preparation, physical properties, - Acidity of phenols, reactions, rearrangement of phenol derivatives-Fries rearrangement, Claisen rearrangement Ethers – preparation, physical properties, reactions – cleavage by acids. Synthesis and Reactions of Epoxides, Cleavage of ether linkages by HI- Ziesels method of estimation of methoxy groups.

UNIT – 3 **(10 hrs)**

Carbonyl compounds A: Aldehydes and Ketones

Physical properties, preparation, reactions – Cannizaro reaction, Aldol condensation, Wittig reaction, nucleophilic addition - addition of cyanide, derivatives of ammonia, Grignard reagent, alcohols, oxidation and reduction – Baeyer-Villiger oxidation-Cannizzaro's reaction, Meerwein-Ponndorf Verley reduction, Clemmensen reduction, Wolff-Kishner reduction, $LiAIH_4$ and $NaBH_4$ reductions, α, β – unsaturated carbonyl compounds – Claisen, Claisen-Schmidt, Dieckmann, Benzoin, Aldol, Perkin and Knoevenagel condensations, nucleophilic and electrophilic addition – Michael addition and Robinson annulation, Mannich reaction. Alkylation of carbonyl compounds *via* enamines.

Compounds containing active methylene groups.

UNIT – 4 **(10hrs)**

Carbonyl compounds B: Carboxylic Acids and acid chlorides & esters

Physical properties – Acidity of carboxylic acids – effect of substituents, preparation, reactions – salt formation and decarboxylation, preparation and reactions of functional derivatives, halogenation of aliphatic acids - Hell-Volhard- Zelinsky reaction.

Methods of formation and chemical reactions of anthranilic acid, cinnamic acid, acrylic acid, oxalic acid, malonic acid, citric acid, adipic acid, maleic acid, fumaric acid. Preparation and reactions of benzene sulphonic acid, benzene sulphonyl chloride and ortho and para toluene sulphonyl chlorides- uses. Esters, hydroxyl acids, lactones.

Synthetic uses of malonic ester, acetoacetic ester and cyanoacetic ester. Keto-enol tautomerism of ethyl acetoacetate.

UNIT – 5 **(10 hrs)**

Nitrogen containing compounds

Amines- isomerism- stereochemistry of amines, distinguish between primary, secondary and tertiary amines- Structural features affecting basicity of aliphatic and aromatic amines. Quaternary amine salts as phase-transfer catalysts. Comparative study of aliphatic and aromatic amines. Preparation of alkyl and arylamines (reduction of nitro compounds, nitriles), reductive amination of aldehydic and ketonic compounds, Gabriel-Phthalimide reaction, Diazonium salts- preparation, synthetic transformations of aryl diazonium salts, azo coupling- . Mechanisms of Sandmeyer's and Gatterman reactions- Schiemann and Gomberg reactions Preparation and uses of Phenyl hydrazine. Diazomethane and diazoacetic ester - preparation, structure and synthetic uses -Arndt Eistert synthesis- mechanism –Wolff rearrangement. Amides - preparation and reactions.

Recommended Text Books:

1. Bruice, P.Y. Organic Chemistry, 7th Ed., Prentice Hall Inc., 2013.
2. Morrison, R.T. Boyd, R.N. and Bhattacharjee, S.K. Organic Chemistry, 6th Ed.,
3. Pearson Education Inc., 2014.
4. Clayden, J. Green, N. Warren, S. and Wothers, P. Organic Chemistry, 2nd Ed., Oxford University Press, 2012
5. McMurry, J. Organic Chemistry, 5th Ed., Brooks/Cole, 2000.
6. Bruckner, R. Advanced Organic Chemistry: Reaction Mechanisms, 1st Ed., Academic Press, 2001.
7. Carey, F.A. and Sundberg, R.J. Advanced Organic Chemistry (parts A and B),

5th Ed., Springer, 2008.

8. Norman, R.O.C. Principles of Organic Synthesis, 2nd Ed., Chapman and Hall, 1978.
9. Solomons, T.W.G. Fryhle, C.B., Snyder, S. A. Organic Chemistry, 12th Ed., Global, 2017.
10. Smith Janice G., Organic Chemistry 3rd Edn., McGraw-Hill, 2011.

CORE

CHE 10504

PHYSICAL CHEMISTRY- I

(EQUILIBRIUM THERMODYNAMICS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	Cognitive level
C.O. 1: Predict changes in thermodynamic parameters during a process and predict the spontaneity.	Apply
C.O. 2: Describe the significance of chemical potential in physical and chemical processes	Apply
C.O. 3: Understand thermodynamics of phase transitions and interpret phase diagram of a given system.	Analyse
C.O. 4: Interpret dependence of chemical equilibrium on pressure, temperature and concentration.	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X	X			X					
C.O.2	X	X			X					
C.O.3	X	X			X					
C.O.4	X	X			X					

UNIT – 1 **(8 hrs)**

Language and Mathematics of Thermodynamics.

Recap of first and second law. The Clausius inequality, Free energy functions - Variation with temperature and pressure. Gibbs Helmholtz equation. Relation between thermodynamic functions. Maxwell relations-significance.

Third law of thermodynamics: Nernst Heat Theorem, Calculation of absolute entropy, Unattainability of absolute zero.

UNIT – 2 **(10 hrs)**

Thermodynamic systems of variable composition – Partial molar properties. Chemical Potential, Significance of Chemical potential, Gibbs Duhem Equation and Duhem Margules Equation. Thermodynamics of mixing. Excess functions, Concepts of activity and fugacity, Standard states.

UNIT – 3 **(10 hrs)**

Physical transformation of Pure substances- Stability of a phase, Phase transitions and phase boundaries- Thermodynamic aspects, Ehrenfest Classification of Phase transitions. Phase rule – Application to one component systems- Water, S, CO_2 and He.

UNIT – 4 **(10 hrs)**

Thermodynamics of Binary systems: Binary liquids- Ideal solutions, Raoults law, Henry's Law, Deviations from ideality, Real and Regular solutions, Excess functions, Ideal Dilute Solutions- Colligative Properties- van't Hoff factor.

Liquid-vapour equilibria of binary systems – Vapour pressure-composition diagrams and Temperature composition diagrams. Distillation of binary mixtures –Azeotrope formation.

Liquid-liquid equilibria- Partially miscible and immiscible liquids- CST, Nernst Distribution Law, Partition co-efficient, Principle of Steam distillation.

Solid-liquid Equilibria-Cooling curve, Eutectic system, Deep Eutectic solvents, Application, Compound formation with Congruent and Incongruent melting points. Salt hydrate water systems,

Solid-Vapour Equilibria- $CuSO_4$-water system. Three component systems.

UNIT – 5 **(10 hrs)**

Chemical Equilibria and free energy, Equilibrium Constants, Applications of free energy function to physical and chemical changes- Le Chateliers Principle. Effect of temperature and pressure on chemical equilibrium- van’t Hoff reaction isotherm and isochore.

Recommended Text Books:

1. Peter Atkins and Julio de Paula, Physical Chemistry, Oxford University Press, 8th and10th Edn, 2017.
2. D.A McQuarrie, J.D Simon, Molecular Thermodynamics, Viva Student Edn. 2010.
3. I.N Levine, Physical Chemistry, McGraw Hill Indian Edn, 2011.
4. I. M. Klotz & R. M. Rosenberg, Chemical Thermodynamics, Wiley, 7th Edn, 2008.
5. L. K. Nash, Elements of Chemical Thermodynamics, Addison Wesley, 2nd Edn, 2013.
6. F. Daniels and R. A. Alberty, Physical Chemistry, Wiley Publishers, 4th Edn 2004

CORE

CHE 10505

MATHEMATICS FOR CHEMISTS

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Solve mathematical problems	Apply
C.O. 2: Apply the principles of mathematics to chemical systems /processes	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x								
C.O.2	x	x								

UNIT – 1 **(4 hrs)**

Numbers: Real and Complex number algebra. Vector algebra.

UNIT – 2 **(6 hrs)**

Functions & Variables: Differential calculus-first- and higher-order derivatives, evaluation of minimum and maximum, limits & continuity. Partial differentiations. Exact and inexact differentials. Numerical differentiation. The gamma and delta functions.

Integral Calculus: Indefinite and definite integrals, improper integrals. Methods of integration. Surface and volume integrals. Numerical integrations.

UNIT – 3 **(8 hrs)**

Differential Equations: Ordinary first- and second-order differential equations.

Partial differential equations. Solution of inexact differential equations by the method of integrating factors. Power series and extended power series solutions. Numerical solutions.

UNIT – 4 **(8hrs)**

Special functions: Hermite, Legendre and Laguerre polynomials, recursion relations. Matrices and Determinants. Eigenvalues and eigenvectors. Orthogonal transformation. Rank & inverse ofmatrix.

UNIT – 5 **(6 hrs)**

Solution of Linear Systems: Gaussian elimination, Cramer's rule. Gauss-Jordan elimination. Gauss-Seidel and Jacobi methods. Solution of non-Linear Systems: Newton-Raphsonmethod.

Curve fittings. Permutation & Combination. Probability. Stirling's approximation. Lagrangemultipliers.

Recommended Text Books:

1. Mortimer, R. G, Mathematics for Physical Chemistry. 3rd Edn., Academic Press.2014
2. Kreyszig, E., Advanced Engineering Mathematics. 9th Edn. Wiley,2015
3. Turrell, G., Mathematics for Chemistry and Physics, 2nd Edn., Academic Press,2004
4. McQuarrie, D. A., Mathematics for Chemists and Physicists, 4th Edn., Wiley,2007

CORE/LAB

CHE 10506

INORGANIC CHEMISTRY LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Estimate the amount of a given metal ion by complexometric reactions	Apply
C.O. 2: Identify the cation from the given mixture	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x		x	x					
C.O.2	x	x	x	x	x					

UNIT – 1 **(96 hrs)**

1. Complexometry
2. Estimation of Zinc Estimation of Magnesium
3. Estimation of different metal ions from a mixture – use of masking agents
4. Analysis of less common ions
5. Separation and identification of two less familiar metal ions such as Tl, W, Se, Mo, Ce, Th, Ti, Zr, V, U and Li from a mixture of salts.

Recommended Text Books:

1. Vogel's Textbook of Quantitative Chemical Analysis 6^{th} Ed., Pearsons EducationLtd.
2. A.I. Vogel, G. Svehla, Vogel's Qualitative Inorganic Analysis, 7th Edn., Longman,1996.
3. V.V. Ramanujam, Inorganic Semimicro Qualitative Analysis, The National Pub.Co., 1974.
4. Laboratory Manual, CHE 10506, Department of Applied Chemistry,CUSAT

CORE/LAB

CHE 37

ORGANIC CHEMISTRY LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Prepare organic compounds through one step synthesis and purify and recrystallize the product	Analyse
C.O.2: Apply analytical techniques for the quantitative and qualitative analysis of organic molecules	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x		x						
C.O.2	x	x		x						

UNIT – 1 **(96 hrs)**

One step synthesis of Organic Compounds Estimation of organic compounds Separation of organic binary mixtures –liquid-liquid extraction, column chromatography. Purity assessment of the isolated components by TLC & GC.

Recommended Text Books:

5. Pavia, D.L. Lampman, G.M. Kriz, G.S. and Engel, R.G. Introduction to Organic Laboratory Techniques: A small scale Approach, 2nd Ed., 2007.
6. Dey, B.B. Sitaraman, M.V. and Govindachari, T.V. Laboratory Manual of Organic Chemistry, 3rd Ed., Viswanathan, 1957.
7. Furniss, B.S. Hannaford, A.J. Smith, P.WG. Tatchell, A.R. Vogel's Textbook of Practical Organic Chemistry, 5th Ed., Longman, 1989.
8. Mann, F.G. Saunders, B.C. Practical Organic Chemistry, 4th Ed., Pearson Education India, 2009.
9. Clark, H.T. A handbook of organic analysis, Longman, 1966.
10. Laboratory Manual, CHE 10707, Department of Applied Chemistry, CUSAT.

CORE/LAB

CHE 10508

OPEN ENDED LAB-I

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validating the hypothesis.

The students shall submit a project report and appear for viva-voce.

CORE

CHE 10601

INORGANIC CHEMISTRY – II

(COORDINATION CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Explain the properties of transition metals and lanthanides	Apply
C.O.2: Describe and explain the structure, bonding and magnetism in transition metal complexes using crystal field theory and ligand field theory	Analyse
C.O. 3: Describe various metal-ligand interactions in terms of sigma- and pi-bonding	Evaluate
C.O. 4: Explain the stability of transition metal complexes, their reactivity, and the mechanisms of ligand substitution and redox reactions	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					

UNIT – 1 **(8 hrs)**

General periodic trends of d and f block elements, Metallic property, Chemistry of variable oxidation states, properties of d configuration - d^0 to d^{10}, Type of compounds. Lanthanides and Actinides- Stable oxidation states, lanthanide and actinide contraction, Occurrence and recovery; Separation of

Lanthanides; difference between 4f and 5f orbitals.

UNIT – 2 **(10 hrs)**

Werner's theory, Bonding in coordination compounds: Valence bond description and its limitations. valence bond theory (inner and outer orbital complexes), Crystal Field Theory (CFT). measurement of 10 Dq (Δ_o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δ_o, Δ_t). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, Jahn – Teller effect in octahedral complexes, square planar geometry.

UNIT – 3 **(10 hrs)**

Factors affecting the crystal-field parameters. Spectrochemical series, colour and spectral behaviours. magnetism of first-row transition metal complexes, stabilization of unusually low and high oxidation states of metals, Ligand field theory and Qualitative aspect of MO Theory, Effect of π-donor and π- acceptor ligands in LFSE, back bonding. Application of crystal filed theory, lattice energies, ionic radii, site preferences in spinels. Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

UNIT – 4 **(12 hrs)**

Definition and Classification with appropriate examples based on nature of metal-carbon bond (ionic, s, p, and multicentre bonds), metal-metal multiple bonding, Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, EAN rule as applied to carbonyls, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. Preperation and Structures of mononuclear and binuclear carbonyls of Cr,Mn, Fe, Co and Ni. π-acceptor behaviour of CO, synergic effect and use of IRdata to explain extent of back bonding. Zeise's salt: Preparation and structure,evidences of synergic effect and comparison of synergic effect with that in carbonyls.

Semester 6

Organo-lithium aluminium, magnesium, zinc and titanium compounds – their preparations, properties, reactions, bonding and applications. ‘‘Sandwitch’’ compound: Ferrocene – its preparation, reactions and structure.

UNIT – 5 **(8 hrs)**

Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans-effect, theories of trans effect, Mechanism of nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Labile and inert complexes, Kinetics of octahedral substitution, Ligand field effects and reaction rates. .

Recommended Text Books:

1. Purcell, K.F & Kotz, J.C. Inorganic Chemistry, 2nd Ed., W.B. Saunders Co, 1991.
2. Huheey, J. E., Keiter, E. A. and Keiter, R. L. Inorganic Chemistry, Principle and structure and reactivity, 4th Ed., Harper Collins College Publishers, New York, 1993.
3. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry 2nd Ed., University Science Books, 1994.
4. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley- Interscience, 1999.
5. Basolo, F, and Pearson, R.C., Mechanisms of Inorganic Chemistry, 2nd Ed., John Wiley & Sons, NY, 1967.
6. Greenwood, N.N. & Earnshaw A., Chemistry of the Elements, 2nd., Ed. Butterworth-Heinemann,1997.
7. Miessler, G.L. & Tarr, D. A. Inorganic Chemistry, 5th Ed., Pearson Publication, 2013.
8. Sharpe, A.G. Inorganic Chemistry, 4th Indian Reprint, Pearson Education, 2005.

9. Douglas, B. E.; McDaniel, D.H. and Alexander, J.J. Concepts and Models in Inorganic Chemistry 3rd Ed., John Wiley and Sons, NY, 1994.
10. Powell, P. Principles of Organometallic Chemistry, 2nd Ed., Springer, 1991.
11. Shriver, D. F., Atkins, P. W. and Langford, C. H. Inorganic Chemistry, 4th Ed., W.H. Freeman & Company, 2006.
12. Crabtree, Robert H. The Organometallic Chemistry of the Transition Metals. 6th Ed., New York, NY: John Wiley, 2014.
13. W. L. Jolly, Modern Inorganic Chemistry, McGraw-Hill International, 2nd Edition, New York, 1991.

CORE

CHE 10602

ORGANIC CHEMISTRY-II
(STRUCTURE, STEREOCHEMISTRY AND CONFORMATIONAL ANALYSIS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Appraise Molecular Orbital Theory and group orbital concepts to sketch MO's of common organic molecules and reactive intermediates	Analyze
C.O.2: Apply the concepts of isomerism and analyse the conformation and configuration of organic molecules.	Apply
C.O.3: Analyze the conformational effects on the reactivity of various reactions	Analyze
C.O.4: Understand the conformation and stereo-electronic effects of carbohydrates	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		

UNIT – 1 **(10 hrs)**

MO theory and Frontier orbitals: Qualitative Molecular Orbital Theory, Group orbitals, Hyper conjugation, Negative – Hyperconjugation, Anomeric effect. Conjugated Systems, Huckels rule and Modern theory of Aromaticity.Substituent effects on frontier orbitals. Study of Structure and Stability of Reactive intermediates: Carbocations, Carbanions, Carbenes, Nitrenes, and

Radicals.

Study of Bonding Weaker than Covalent Bonds: Ion pairing interactions, ion – dipole interactions, dipole – dipole interactions, Hydrogen bonding, Factors affecting strength and stability of hydrogen bonds, cations – π, polar – π, π-stacking, π-donor – acceptor interactions, induced dipole interactions, the hydrophobic effect.

UNIT – 2 **(10 hrs)**

Geometrical & Optical isomerism: origin of chirality, chiral centres and configuration, axes and planes, helicity. Topicity relationships, enantiotopic and diastereotopic, groups and faces, prochiral centres and faces. Symmetry, stereochemistry and time scale. Allenes, cumulenes, biphenyls, and spirans. Compounds containing chiral atoms other than carbon. Topological and Supramolecular stereochemistry.

Brief introduction to CD and ORD techniques, octant rule, axial haloketone rule, and sign of Cotton effect

UNIT – 3 **(8 hrs)**

Conformational analysis: Strain, types of strain including *B, F, I*, Pitzer strain, Beyer strain. Acyclic sp^3–sp^3, sp^3-sp^2 systems, structure and stability of small, medium, and large rings, cyclohexane, substituted cyclohexanes, *A* values, cyclohexenes, decalins, bicyclic systems.

UNIT – 4 **(10hrs)**

Reaction Mechanisms and Conformational Effects on Reactivity - Ester Hydrolysis, Alcohol Oxidations, S_N2 Reactions, Elimination Reactions, Epoxidation by Intramolecular closure of Halohydrins,

Epoxide Openings (S_N2), Electrophilic Additions to Olefins, Rearrangement Reactions, Conformational and Stereoelectronic Effects on Reactivity. Baldwins rules for ring closure.

UNIT – 5 **(10 hrs)**

General introduction to carbohydrates: Structure and stereochemistry of monosaccharides, disaccharides, mutarotation, glyoxal, stepping up and stepping down, reducing and non-reducing sugars, glycosidic linkage, O & N glycosides. Conformation and Stereo-electronic Effects of carbohydrates: *D* and *L* sugars, Chair conformation, Endo/Exo-anomeric effect, Reverse anomeric effect, Glycosidic torsion angles, Hydroxymethyl group conformation. Conformation and stability of aldohexoes, structure and conformation of ribose and deoxyribose.

Recommended Text Books:

1. March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 7^{th} ed. 2013, Wiley
2. T H. Lowry and K.S. Richardson: Mechanism and Theory in Organic Chemistry, 3rd ed. 1997, Benjamin-Cummings Publishing Company.
3. F. A. Carey and R. J. Sundberg: Advanced Organic Chemistry (parts A and B), 5^{th} Edition 2008, Springer.
4. E. V. Anslyn and D. A. Dougherty: Modern Physical Organic Chemistry. I^{st} ed. 2006, University Science Books,
5. F. A. Carroll: Perspectives on structure and mechanism in organic chemistry, 2^{nd}edition, 2011 Wiley.
6. N. S. Issacs: Physical Organic Chemistry, Second Edition, 2^{nd} Edition, 1995, Prentice Hall.
7. A. Pross: Theoretical and Physical Principles of Organic Chemistry, I Edition,1995, Wiley.
8. J. Clayden, N. Green, S. Warren and P. Wothers: Organic Chemistry, 2^{nd} Edition. 2012, Oxford University Press,

9. P.S.Kalsi: Stereochemistry, Conformation and Mechanism, 3rd Edn., New Age Publications

10. E. L. Eliel and S. H. Wilen: Stereochemistry in Organic Compounds, 1994, John Wiley.

11. S. H. Pine: Organic Chemistry, 5th edition, 2008, McGraw Hill

12. I. Flemming: Molecular orbitals and organic chemical reactions, student edition, 2009, Wiley.

13. J. McMurry, Organic Chemistry, Fifth Edition, 2000, Brooks/Cole .

14. D. Nasipuri, Stereochemistry of Organic Compounds: Principles and Applications, Second Edition, 1994, Wiley Eastern Limited, New Delhi.

CORE

CHE 10602

PHYSICAL CHEMISTRY- II

(ELECTROCHEMISTRY, SOLID STATE AND LIQUID STATE)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Describe the theories effecting ionic conductance and apply the concepts to calculate conductance of a given system.	Apply
C.O. 2: Describe the mechanism of electronic conductance process in charged interfaces.	Apply
C.O. 3: Describe the regular arrangement of atoms in crystals and the symmetry of their arrangement	Analyse
C.O. 4: Understand properties of solids and liquids, and see how their mechanical, electrical, optical, and magnetic properties stem from the properties of their constituent atoms and molecules.	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X	X			X					
C.O.2	X	X			X					
C.O.3	X	X			X					
C.O.4	X	X			X					

UNIT – 1 **(8 hrs)**

Introduction- Ionics, Electrodics, Electrochemical Cells, Electrodes, Electrolytes, Half Reactions, Electrochemical Work, Equilibrium electrochemistry-Half-reactions and electrodes, Types of cells, Types of electrodes- Standard hydrogen electrode, Calomel electrode, Quinhydrone electrode. Ion – Solvent, Ion – Ion

Interactions, Ionic and Electronic Conductance, Conductance Measurement, Equivalent Conductance, Kohlrausch's Law, Ostwalds dilution law, Ionic Mobility, Walden's rule, abnormal conductance, Conductometeric titrations.

UNIT – 2 **(12 hrs)**

Transport Number- Factors Influencing, measurement- Hittorf's and moving boundary methods. Debye-Huckel Theory, Ionic Atmosphere, time of Relaxation, Mechanism of Electrolytic Conductance, Debye Huckel Onsager equation for strong electrolytes. Electrode – Ion interface, liquid junction potential, Double Layer, Overvoltage (Elementary idea).

The electromotive force, Standard potentials, Applications of standard potentials, Determination of solubility product and activity co-efficient, pH determination, Potentiometric titrations, Redox indicators principle. Activity and Activity Coefficient of Electrolytes. Corrosion of metals- different forms of corrosion and prevention. Electrochemical Theory of corrosion – methods of prevention. Fuel Cell, Batteries (Elementary idea)

UNIT – 3 **(12 hrs)**

Symmetry as a universal theme, Molecular symmetry, Symmetry elements and operations, Point groups, Matrix representation of symmetry operations, character, Definition of a mathematical group, Abelian group, Cyclic group, symmetry operations as group elements, symmetry and isomerism, Symmetry classification of molecules into point groups (Schoenflies symbol). Group multiplication table. Crystal structures and symmetry, Crystallographic point groups, space group, unit cells, Miller indices, Seven crystal systems and Bravais lattices, Simple, body centered and face centered systems, Packing in solids- packing diagrams, close packing,- hcp and ccp structures, XRD, Braggs equation – derivation, Powder and rotating crystal technique. Identification of cubic crystals based on interplanar ratio

UNIT – 4 **(8 hrs)**

Ionic solids with formula MX (CsCl, NaCl, Zinc Blende and Wurtzite

Structures), MX2 (Fluorite and Antfluorite Structures, Cadmium Halides, CaF2, Rutile, Anti-rutile, betacristobalite), other crystal systems (Bismuth tri-iodide, Corundum, Rhenium Trioxide etc.), Mixed oxides (Spinel, Perovskite, Ilmenite). The properties of solids **,** Mechanical properties Electrical properties, Impact on nanoscience: Nanowires, Optical properties , Magnetic properties.

Point Defects in crystals- stoichiometric and non-stoichiometric defects, Line defect, surface defects, Liquid Crystals- Classification and application.

UNIT – 5 **(8 hrs)**

Vapour pressure , Surface tension - determination of vapour pressure. Parachor – determination, application to structure elucidation of compounds, Viscosity - determination of molecular mass from viscosity measurements. Refraction – refractive index, molar refraction and optical exaltation – application to structure elucidation, Concept of superhydrophobicity/super-leophilcity.

Recommended Text Books:

1. J. Bockris and A.K.N. Reddy, Modern Electrochemistry, 2nd Edn., Wiley, New York, 1998
2. R. Crow, Principles and Applications of Electrochemistry, Paper back edn, 4th edn, 1994.
3. S. Glasstone, An Introduction to Electrochemistry, Paperback edn., 2007
4. L.V. Azaroff, Introduction to Solids, Mc Graw Hill, 1960.
5. A. R. West, Solid State Chemistry, Wiley Student (Indian) Ed., (2014)
6. A.K. Galwey, Chemistry of Solids, Chapman and Hall, London, 1967. 35
7. Lesley Smart and Elaine Moore, Solid State Chemistry, Chapman and Hall, 1995.
8. H. V. Keer, Principles of the Solid State Wiley Eastern Ltd, New Delhi, 1993.
9. C. N. R. Rao and J. Gopalakrishnan, New Directions in Solid State Chemistry. 2 nd edn, Cambridge Uty Press, 1997.

CORE

CHE 10604

INDUSTRIAL CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe the sustainable management of chemicals	Apply
C.O.2: Preform quality analysis of chemical products	Analyse
C.O.3: Evaluate the factors influencing the industrial scale up of chemical synthesis	Evaluate
C.O.4: Explain and prepare flow chart for preparation of chemicals	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x		x	x	x	x	x		
C.O.2	x	x		x	x	x	x	x		
C.O.3		x		x	x	x	x	x		
C.O.4		x	x	x	x	x	x	x		

UNIT – 1 **(10 hrs)**

Source of Chemicals, Organic Chemicals, Inorganic Chemicals, Recycling of materials, waste minimization, E factor and atom economy, Reduction of-material use. Water management – water for industry, sources of water, water conditioning methods, municipal waste water, Industrial waste water –treatment. Energy Management- energy required by chemical industries, sourcesof energy, cost of energy, types of energy requirement, use of energy, efficient utilization of energy., energy, risk and hazards. Sustainable use of- chemical feedstocks, water, energy. Environmental pollution control – methods of pollution control, economics of pollution control, industrial health and hygiene.

UNIT – 2 **(10 hrs)**

Industrial Processes in practice – Basic chemical data, Flow charts; chemical process selection, design and operation, Plant location, safety, construction of plant, process system engineering. Case study of chemical industry of regional importance. Pharmaceutical Industries – Classification, methods of preparation, radioisotopes in medicine, biological hormones, steroids, vitamins, plant and animal isolates, drug design (basic understanding)

UNIT – 3 **(10 hrs)**

Fuel Industries – Calorific value, modern concept of fuels, classification, criteria for selection, comparison of gas, liquid and solid fuels, properties, methods of processing various fuels, solid fuels , Gaseous fuels, Petroleum – occurrence, mining, product of refining, Processing, color and constituency, classification and composition, grading of petroleum, determination of flash point, knocking, antiknock compounds, octane number, cetane number, chemical treatment to upgrade liquid fuel, Petrochemicals.

UNIT – 4 **(10hrs)**

Agrichemical Industries- Fertilizers – Fertilizer type, need for fertilizer, essential requirements, plant nutrients and regulators, soil fertility, pH of soil, classification of fertilizer, natural fertilizers, nitrogenous fertilizer, Phosphate fertilizers, NPK fertilizers, effect of fertilizer- pollution. Insecticides-classification, DDT, BHC, Gammexane, Endosulfan. Attractant and repellants.

Introduction to nutraceuticals: definitions, synonymous terms, claims for a compound as nutraceutical, regulatory issues. Study of Properties, structure and functions of various Nutraceuticals (3 examples) formulation of functional food, stability, analysis. Food as remedies, Anti-nutritional Factors present in Foods, Nutraceutical Industry and Market Information.

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Synthetic uses of malonic ester, acetoacetic ester and cyanoacetic ester. Keto-enol tautomerism of ethyl acetoacetate.

UNIT – 5 **(8 hrs)**

Rubber Industries – Chlorinated and oxygenated rubber, latex, coagulation, crude natural rubber, vulcanization, physical and chemical properties. Synthetic rubbers-SBR, silicone rubber, reclaimed rubber, foam rubber, rubber cement, applications, Rubber derivatives. Leather – manufacture, tanning of leather – vegetable tanning, chrome tanning, oil tanning. Synthetic Fibers – properties, preparation, requirements, difference between synthetic and natural fiber. Rayon, Nylon, Orlon, Teflon.

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Recommended Text Books:

11. C. A. Heaton, An Introduction to industrial chemistry, 2nd edition, 1991,Blackie.
12. George T. Austin, Shreve's Chemical Process Industries, 5th edition, 1984, McGraw Hill International.
13. B. K. Sharma, Industrial Chemistry (including Chemical Engineering), 1997, GOEL PublishingHouse.
14. M. Farhat Ali, Bassam El Ali, Handbook of Industrial Chemistry: Organic Chemicals, 2005, McGraw Hill Professional.
15. Fritz Ullmann, Ullmann's Encyclopedia of Industrial Chemistry, 1999-2014, John Wiley and Sons,Inc.
16. A. K. De, Environmental Chemistry, 7th edition, 2013, New Age International Publishers.

17. G. E. J. Poinern, A Laboratory Course in Nanoscience and Nanotechnology, 2015, CRC Press Taylor & FrancisGroup.

CORE

CHE 10605

MATHEMATICS FOR CHEMISTS

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	Cognitive level
C.O. 1: Describe different numerical methods and apply them to solve simple chemical problems	Apply
C.O. 2: Write FORTRAN programmes for solving simple chemical problems using the numerical methods	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x								
C.O.2	x	x					x			

UNIT – 1 **(6 hrs)**

Programming in FORTRAN: Program design (algorithm), organization of program, data types and integer constants, complex constanta, logical constants, variables, implicit and explicit data typing, expressions and hierarchy of operations, mix-mode arithmatic, library functions, input/output specification, formatting, unconditional transfers, conditional statements and constructs, GO TO/ IF statements, relational operators, block if structure, else if construct, do loops, nesting, variables and arrays, parameter/data statements, common blocks, read/write by opening files, subroutines and construction of largeprogram.

UNIT – 2 **(6 hrs)**

Numerical Methods: Taylor's theorem, Expansion of functions, Remainder,Mean value and Extreme value theorems, Discrete average value theorem.Numerical Differentiation (first, second and higher derivatives) - Truncationand Round-off errors, Step size dilemma, Difference table (Pascal's triangle).

UNIT – 3 **(4 hrs)**

Numerical Integration - Riemann sum, Quadrature rule, Interpolating polynomials (Lagrange's), Weights, Mid-point, Trapezoidal, Simpson's rule of integration, Adams' Predictor-Corrector method. Roots of equations- Newton- Raphson and Secant methods, Bisection and False-point methods, Bracketing method.

UNIT – 4 **(8hrs)**

Numerical solution of ordinary differential equations- Initial value problems, Euler's method, Taylor and Runge-Kutta methods, Modified Euler and Hugen's method, Error estimates. Curve fitting- Least square fit algorithm, Monotone and convex data. Linear systems- Forward, Backward substitution, LU- factorization, pivoting (only basics), Gaussian Elimination, Gauss-Jordan Elimination, Jacobi and Gauss-Seidel methods. Eigenvalue problems. Statistical analysis of data.

UNIT – 5 **(8 hrs)**

Programming Laboratory (Linux OS, vi editon): Students are instructed to write programs on some of the numerical methods taught. Programming in FORTRAN (FORTRAN 77 Standard)

Examples of numerical algorithms – algebraic equations, numerical integration, curve fitting, matrix computations

Recommended Text Books:

1. Schatzman, M., Numerical Analysis: A Mathematical Introduction, 2ndEdn. Oxford University Press,2012
2. McCormick, J. M., Salvadori, M. G., Numerical Methods in Fortran, Prentice Hall of India,2009
3. Burden, R. L., Faires, J. D., Numerical Analysis, 2ndEdn. Brooks/Cole,2012.
4. Epperson, J. F., An Introduction to Numerical Methods and Analysis, John Wiley and Sons, Inc.,2014
5. Maron, M. J., Numerical Analysis: A Practical Approach, , Macmillan,2008.
6. Hildebrand, F. B., Introduction to Numerical Analysis, McGraw Hill, New York,2007.
7. Xavier, C., Fortran 77 and Numerical Methods, 2ndEdn., New Age International Publishers,2011

9. Rajaraman, V., Computer Programming in Frotran, PHI Learning,1995.
10.Mollah,S.A.,NumericalAnalysisandComputationalProgramming,AlliedPublishers Ltd,2011

CORE/LAB

CHE 10606

ADVANCED PHYSICAL CHEMISTRY LAB – I

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Verify the concepts and laws in physical chemistry	Evaluate
C.O.1: Execute and perform experiments based on CST, Rast method, Transition temperature and Hall effect for the determination of various physical properties	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x							x	
C.O.2	x	x		x	x				x	

UNIT – 1 **(96 hrs)**

6. Enzyme Kinetics
7. C.M.C. determination
8. CST
   Determination of mutual solubility of phenol-water system Influence of KCl, Succinic acid on CST of phenol-water system- Estimation of concentration of unknown solution
9. RAST METHOD
   Determination of molal depression constant of naphthalene -determination of molecular weight of solute
10. TRANSITION TEMPERATURE
    Determination of transition temperature of salt hydrate-water system Determination of molecular weight of solute ;Viscosity, molecular weight of polymers
11. Intermolecular hydrogen bonding in benzyl alcohol using infrared spectroscopy
12. HALL EFFECT EXPERIMENT

Recommended Text Books:

18. J. N. Gurtu, and A. Gurtu Advanced Physical Chemistry Experiments, 6th Ed., Pragati Prakashan,2014.
19. J. B. Yadav, Advanced Practical Physical Chemistry, 36th Ed., Krishna Prakashan, 2016.
20. Laboratory Manual, CHE 10606, Department of Applied Chemistry, CUSAT

CORE/LAB

CHE 10607

INDUSTRIAL CHEMISTRY LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Prepare and analyze industrially important chemical products	Create
C.O. 2: Prepare the treatment methods for conversion ofnatural resources to value added chemicals	Create

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1			X	X				X	X	
C.O.2			X	X				X	X	

UNIT – 1 **(96 hrs)**

13. Preparation of soap and detergents
14. Preparation of margarine
15. Preparation and physical property measurement of natural, synthetic rubber, fiber.
16. Extraction of essential oils
17. Extraction of natural flavors
18. Preparation of Biogas
19. Waste water treatment
20. Preparation and characterization of nanomaterials
21. Preparation of silicon from Rice Husk
22. Galvanization/powder coating

Recommended Text Books:

21. J. N. Gurtu, and A. Gurtu Advanced Physical Chemistry Experiments, 6^{th} Ed., Pragati Prakashan,2014.

22. J. B. Yadav, Advanced Practical Physical Chemistry, 36th Ed., Krishna Prakashan, 2016.

23. Laboratory Manual, CHE 10606, Department of Applied Chemistry, CUSAT

CORE/LAB

CHE 10608

OPEN ENDED LAB-II

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validating the hypothesis.

The students shall submit a project report and appear for viva-voce.

CORE

CHE 10701

INORGANIC CHEMSITRY-III
(CONCEPTS AND DEVELOPMENTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Identify the structure-activity relationship of simple molecules based on their qualitative molecular orbitals.	Analyse
C.O. 2: Predict the stability and topology of different polyhedral boranes and related compounds.	Analyse
C.O. 3: Assess the strength of various acids and bases and their reactivity.	Analyse
C.O. 4: Explain behavior of different non-aqueous solvent systems towards different reactions.	Apply
C.O. 5: Interpret the structure and properties of compounds of sulfur, nitrogen, phosphorous and group 14 elements.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x					
C.O.4	x	x			x					
C.O. 5	x	x			x					

UNIT – 1 **(10 hrs)**

Qualitative molecular orbital theory, symmetry of molecular orbitals, MOs for homo and heteronuclear diatomic molecules, H_2 to F_2, HF, CO, NO, BeH_2, CO_2,

H_2O, BH_3, NH_3, B_2H_6, $B_3N_3H_6$, S_3N_3, $N_3P_3Cl_6$, Si_2H_2. Importance of frontier molecular orbitals, Shape, energy and reactivity of molecules.

UNIT – 2 **(10 hrs)**

Electronic structure and allotropes of boron, boron halides, boron heterocycles, borazine Structure and bonding in polyhedral boranes and carboranes, styx notation; electron count in polyhedral boranes; Wade's rule; topological approach to boron hydride structure. Importance of icosahedral framework of boron atoms in boron chemistry. Closo, nido and arachno structures. Synthesis of polyhedral boranes; electron counting in polycondensed polyhedral boranes, mno rule. Carboranes, metallocarboranes; Boron halides, boron heterocycles, borazine.

UNIT – 3 **(10 hrs)**

Relative strength of acids, Pauling rules, Lux-Flood concept, Lewis concept, Generalized acid-base concept, Measurement of acid base strength, Lewis acid – base interactions, steric and solvation effects, acid–base anomalies, Pearson's HSAB concept, acid-base strength and hardness and softness, Symbiosis, theoretical basis of hardness and softness, electronegativity and hardness.

UNIT – 4 **(8 hrs)**

Chemistry in non-aqueous solvents reactions in NH_3, liquid SO_2, solvent character, reactions in SO_2, acetic acid, solvent character, reactions in H_2SO_4 and some other solvents. Molten salts, Green solvent: supercritical CO_2, Ionic liquids and deep eutectic solvents.

UNIT – 5 **(10 hrs)**

Sulphur-Nitrogen compounds: Tetrasulphur tetranitride, disulphur dinitride and polythiazyl. SxNy compounds. S-N cations and anions. Sulphur-phosphorus compounds: Molecular sulphides such as P_4S_3, P_4S_7, P_4S_9 and P_4S_{10}. Phosphorus-nitrogen compounds: Phosphazenes and poly phosphazenes. Transition metal dichalcogenides, MoS_2. Structure, bonding and reactivity of 2D and 3D Carbon, Silicon and Germanium materials. Carbon nitrides, fullerenes, carbon nanotubes

(CNT's) and graphenes.

Recommended Text Books:

1. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed., Pearson, 2014.
2. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of Structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
3. F. A. Cotton, G. Wilkinson, C. A, Murillo, M. Bochmann, Advanced Inorganic Chemistry, 6th ed., Wiley-Interscience: New York, 1999.
4. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3rd ed., ELBS, 1999.
5. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd ed., Wiley, 1994.
6. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2nd ed., Butterworth-Heinemann, 1997.
7. C.E. Housecroft, A.G. Sharpe, Inorganic Chemistry, 5th ed., Pearson, 2018.
8. E. Wiberg, A.F. Holleman, N. Wiberg, Inorganic Chemistry, Academic Press,2001.
9. A. V. Kolobov, J. Tominaga, Two-Dimensional Transition Metal Dichalcogenides, Springer, 2016.
10. Yu-Chuan Lin, Properties of Synthetic Two-dimensional Materials and Heterostructures, Springer, 2018.
11. Changzheng Wu, Xiaojun Wu, et al, Inorganic Two-dimensional Nanomaterials: Fundamental Understanding, Characterization and Energy Applications, RSC, 2017
12. D.R. MacFarlane, Mega Kar, J.M. Pringle, Fundamentals of ionic liquids, Wiley-VCH, 2017.
13. Yizhak Marcus, Deep Eutectic Solvents, Springer, 2019.
14. J.M. DeSimone and W. Tumas, Green Chemistry Using Liquid and Supercritical Carbon dioxide, D.U.P, 2003.
15. F. M. Kerton , R. Marriott , et al., Alternative Solvents For Green Chemistry, 2nd ed., RSC, 2013.

CORE

CHE 10702

ORGANIC CHEMISTRY -I

(REACTIVITY AND MECHANISMS)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Review different bonding models with emphasis on understanding three dimensional structures of molecules.	Analyse
C.O.2: Study Qualitative Molecular Orbital Theory and group orbital concepts to sketch MO's of common organic structures, functional groups etc.	Evaluate
C.O.3: Apply the concepts of Frontier orbital theory in the study of ionic, radical and pericyclic reactions.	Analyse
C.O.4: Interpret structure and stability of reactive intermediates.	Evaluate
C.O.5: Apply methods and techniques to study mechanisms of organic reactions.	Apply
C.O.6: Predict the reactivity of an organic compound from its structure and based on the reaction conditions.	Evaluate
C.O.7: Propose a reasonable mechanism for a given organic reaction.	Evaluate
C.O.8: Predict the products in a particular reaction considering the stereochemical aspect.	Evaluate
C.O.9: Illustrate the mechanistic pathway of different rearrangement reactions and identify the products.	Analyse
C.O.10: Identify the mechanism and the product in a given reaction under photochemical condition.	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		
C.O.5	x	x						x		
C.O.6	x	x			x			x		
C.O.7	x	x			x			x		
C.O.8	x	x			x			x		
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		

UNIT – 1 **(10 hrs)**

Study of Structure and Models of bonding: VB and MO models of bonding, Structure and Stability of Reactive intermediates: Carbocations, Carbanions, Carbenes, Nitrenes, and Radicals. Bonding Weaker than Covalent Bonds. Solvent and solution properties, solvent scales. Acid – Base properties in non-aqueous systems, acidity scales, Applications of Molecular Orbital Theory in Understanding reactions and Mechanisms. Qualitative MO theory. Group orbitals. Frontier Orbitals, Substituent effects on frontier orbitals, HSAB concept, Nucleophiles and Electrophiles, Perturbation theory of reactivity. Application of Frontier Orbital theory in studying ionic and radical reactions, Ambident electrophiles, α-effect.

UNIT – 2 **(10 hrs)**

The study of reactions and the methods of studying reaction mechanisms.

Classification of reactions according to IUPAC conventions. Reaction mechanism: guidelines on Pushing of electrons. Reactive intermediates: Formation, stability and general reactivity. Methods of determining reaction mechanisms (kinetic and non kinetic methods): The Hammond postulate,
reactivity vs selectivity principle, the Curtin-Hammett principle, microscopic

reversibility, kinetic vs thermodynamic control. Isotope effects: Primary,secondary and Equilibrium isotope effects, Tunneling effects, solvent isotope effects and heavy atom Isotope effects.

Linear free energy relationships: Hammett and Taft parameters, Solvent effects (Grunwald-Winstein plots and Schleyer adaptation), nucleophilicity and nucleofugality. Isokinetic and Isoequilibrium temperature, Enthalpy – entropy compensation. Experimental techniques to determine reaction mechanisms: identification of intermediates by trapping and competition experiments, cross - over experiments, isotope scrambling, radical clocks and traps, matrix isolation

UNIT – 3 **(14 hrs)**

Substitutions on Aliphatic carbon – saturated and unsaturated systems – Mechanism of nucleophilic substitution – SN2, SN1 – ion pairs, SET, Neighbouring group participation – non classical carbocations, SNi, Tetrahedral mechanism. Electrophilic substitution – SE2, SEi, SE1. Free radical substitution. Reactivity – Effect of substrate structure, nature of reagents, solvents and stereochemistry on the outcome of these reactions. Ambident nucleophiles and substrates. Typical reactions involving substitution.

Substitutions on aromatic carbon: Mechanism of electrophilic, nucleophilic and free radical substitutions – orientation and reactivity. Typical reactions involving aromatic substitution.

UNIT – 4 **(16 hrs)**

Mechanisms of polar addition – electrophilic, nucleophilic and free radical addition. Nonpolar additions (excluding pericyclic reactions) - Reactivity and orientation. Eliminations - E2, E1 and E1CB mechanisms, reactivity and orientation. Pyrolytic syn eliminations, α - eliminations, elimination vs. substitution. Typical reactions involving addition and elimination.

Rearrangements involving electron deficient carbon and nitrogen. Mechanism of the following rearrangements: Wagner-Meerwein, Pinacol, Demyanov, dienone-phenol, Favorskii, Wolff, Hofmann, Curtius, Lossen, Schmidt, Beckmann, benzidine, and Hofmann-Loffler, Fries, Baeyer-Villiger rearrangements. Fritsch-Buttenberg-Wiechell rearrangement, Corey-Fuchs reaction, Seyferth-Gilbert homologation, Grubbs catalysts and olefinmetathesis.

UNIT – 5 **(14 hrs)**

Pericyclic reactions: study of the principle of conservation of orbital symmetry: Orbital symmetry diagrams for cycloaddition and electrocyclic reactions. Aromatic Transition State Theory and The Generalized Woodward – Hoffmann rule applied to cycloaddtions, Electrocyclic reactions, Sigmatropic rearrangements and Chelotropic reactions.

Pericyclic Reactions in Organic Synthesis: Stereochemistry and Regiochemistry of Cycloaddtions. Substituent and medium effects, Secondary Orbital Interactions in [4+2] cycloadditions, Intramolecular Diels–Alder reactions. Stereochemistry of Electrocyclic Reactions and Sigmatropic rearrangements. Cope rearrangement, Claisen rearrangement and ene-reaction.

1,3-dipolar cycloaddition reactions, Photochromism and thermochromism, Pericyclic reactions in Organic synthesis – case studies.

Photochemistry: Unimolecular and bimolecular processes in the excited states, mechanism of important photochemical reactions, Paterno-Buchi reaction, Norrish Type I and Type II fragmentation, di-pimethane rearrangement, Barton reaction, photochemistry of olefins, arenes, cyclohexadienones; photoreduction and photo-oxygenation..

Recommended Text Books:

1. J. March, Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 7^{th} ed., Wiley, 2013.

2. T. H. Lowry, K. S. Richardson, Mechanism and Theory in Organic Chemistry, 3rd ed., Benjamin-Cummings Publishing Company, 1997.
3. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
4. E. V. Anslyn, D. A. Dougherty, Modern Physical Organic Chemistry. University Science Books, 2006.
5. F. A. Carroll, Perspectives on structure and mechanism in organic chemistry, Wiley, 2011.
6. N. S. Issacs, Physical Organic Chemistry, 2nd Edition, Prentice Hall, 1995.
7. A. Pross, Theoretical and Physical Principles of Organic Chemistry, 1st ed., Wiley, 1995.
8. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
9. I. Flemming: Molecular orbitals and organic chemical reactions, student ed., Wiley, 2009.
10. J. McMurry, Organic Chemistry, 5th ed., Brooks/Cole, 2000.
11. R. Bruckner, Advanced organic chemistry: Reaction Mechanisms. Academic Press, 2001.
12. P. Sykes, Guidebook to Mechanism in Organic Chemistry, 6th ed., Prentice Hall, 1986.
13. N. J. Turro, Modern Molecular Photochemistry, University Science Books, 1996.
14. N. J. Turro, J. C. Scaiano, V. Ramamurthy, Modern Molecular Photochemistry of Organic Molecules, 1st ed., University Science Books, 2010.

CORE

CHE 10703

THEORETICAL CHEMISTRY-I

(QUANTUM CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Account for the basic principles and concepts of quantum mechanics.	Analyse
C.O.2: Apply the postulates of quantum mechanics to simple systems of chemical interest, such as the particle-in-a-box, harmonic oscillator, rigid rotor, and hydrogenic atoms.	Apply
C.O.3: Derive the variational principle, use it to calculate properties for simple systems of chemical interest.	Analyse
C.O.4: Use perturbation theory to calculate properties for simple systems of chemical interest.	Analyse
C.O.5: Define and explain the Hartree-Fock self-consistent field method.	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		
C.O. 5	x	x						x		

UNIT – 1 **(10 hrs)**

Wave-particle duality, uncertainty principle, postulates of quantum mechanics, Schrödinger equation, Time dependent and time independent Schrodinger wave equation. Its application on some model systems viz., free particle, particle in one, two and three-dimensional box (rectangular and cubical), separation of variables, concept of degeneracy, introduction to quantum mechanical tunneling.

UNIT – 2 **(10 hrs)**

Vibrational motion, Harmonic oscillator, Method of power series, Hermite equation and Hermite Polynomials, Recursion formula, wave function and energy. Rigid rotator, Wave function in spherical polar coordinates, Planar rotator, phi equation, theta equation and solutions Lagendre equation and Lagendre polynomials, Spherical harmonics, Angular momentum operator L^2 and L_z, Space quantization.

UNIT – 3 **(10 hrs)**

H atom, separation into three equations and solutions, Laguerre equation and Laguerre polynomials wave equation and energy of H like systems, quantum numbers and their importance, Radial wave function and radial distribution functions, angular wave function, Shapes of s, p, d and f atomic orbitals.
Postulate of electron spin-orbital and spin functions. Zeeman effect.

UNIT – 4 **(12 hrs)**

Many electron atoms. Approximate methods in quantum mechanics: The variation theorem, linear variation principle and perturbation theory (first order and non-degenerate), application of variation method and perturbation theory to the Helium atom, antisymmetry, Pauli exclusion principle, Slatter determinantal wave functions. Electron spin

UNIT – 5 **(6 hrs)**

Hartree-Fock Self Consistent Field method, The Coulomb and Exchange Operators, The Fock Operator, Koopmans' theorem, Brillouin's theorem, The Roothaan Equations, Slater's treatment of complex atoms, Slater orbitals. Pauli principle, Slater determinant and wave function.

Recommended Text Books:

1. D. A. McQuarrie, Quantum Chemistry, 3rd ed., Univ. Sci. Books, Mill Valley, California, 1983.
2. I. N. Levine, Quantum Chemistry, 6th ed., Pearson Education, London, 2008.
3. P. W. Atkins, R.S Friedman, Molecular Quantum Mechanics, 5th ed., OUP, Oxford, 2012.
4. J. P. Lowe, Quantum Chemistry 3rd ed., Academic Press, New York, 2008.
5. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Book ed., Mc.Graw-Hill, New York, 1982.
6. P.W. Atkins, Physical Chemistry, 8th ed., Wiley, New York, 2006.
7. R. K. Prasad, Quantum Chemistry, 3rd ed., New Age International, 2006.
8. D. J. Griffiths, Introduction to Quantum Mechanics, 2nd ed., 2004.
9. J. J. Sakurai, Modern Quantum Mechanics, 2nd ed., 2010.

CORE

CHE 10704

THEORETICAL CHEMSITRY-II

(GROUP THEORY AND SPECTROSCOPY)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Analyze the symmetry of any given molecule and assign the point group	Analyze
C.O.2: Apply the principles of symmetry and group theory in structure, bonding and spectral characteristics of molecules	Apply
C.O.3: Explain the factors affecting the intensity and broadening of lines in spectra and methods to enhance the sensitivity	Understand
C.O.4: Explain the principles of rotational, vibrational, Raman, electronic, fluorescence and NMR spectroscopy	Understand
C.O.5: Solve problems based on rotational, vibrational, Raman electronic, fluorescence and NMR spectroscopy	Apply
C.O.6: Apply various theoretical aspects to various spectroscopic techniques for prediction of different spectroscopic observations	Analyze

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x					
C.O.2	x	x			x					
C.O.3	x	x			x	x	x		x	
C.O.4	x	x			x	x	x		x	
C.O. 5	x	x			x	x	x		x	
C.O. 6	x	x			x	x	x		x	

UNIT – 1 **(18 hrs)**

Matrix representation of symmetry operations, similarity transformation and classes, Symmetry classification of molecules into point groups (Schoenflies symbol)- Application of symmetry to predict polar and chiral compounds. Reducible and Irreducible representations - Great Orthogonality theorem and its consequences (statement only, proof not needed), Character tables, Reduction formula, construction of character tables for point groups with order ≤6-, Interpretation of character tables. Wave functions as bases for irreducible representations, Direct product.

UNIT – 2 **(12 hrs)**

Application of symmetry to predict polar and chiral compounds. Application of Group theory to Hybridization of atomic orbitals: Construction of hybrid orbitals for AB_3(planar), AB_4(T_d), AB_5(D_{3h}) and AB_6(O_h) type of molecules.

Application of group theory to Molecular Orbital Theory: LCAO and Huckel approximations. Symmetry adapted linear combinations, Projection operators, Application of projection operators to pi-bonding in ethylene, cyclopropenyl systems, benzene and naphthalene. Application of projection operators to sigma bonding in ethylene and $PtCl_4^{2-}$. Molecular orbitals for tetrahedral and octahedral molecules.

UNIT – 3 **(12 hrs)**

Spectroscopy and its importance in chemistry. Link between spectroscopy and quantum chemistry, Energy levels in molecules, Born-Oppenheimer approximation,

Absorption and emission of radiation, Intensity and width of spectral lines, Beer lambert's law, Integrated absorption coefficient, Line width – natural line broadening, Doppler broadening, minimisation of line broadening, Induced and spontaneous transitions, correlation to the Einstein coefficients of absorption and emission, Basis of selection rules Fermi golden rule, lasers.

UNIT – 4 **(12 hrs)**

Rotational spectroscopy: Rotation of rigid bodies, moment of inertia, linear molecules, spherical, symmetric and asymmetric tops, Schrödinger equation of a rigid rotator and brief discussion of its results, Quantization of rotational energy levels, selection rules, rotational spectra and line intensities, structure determination from rotational constants, isotopic effects.

Vibrational Motion: Schrödinger equation of a linear harmonic oscillator and brief discussion of its results, concept of zero-point energy. Quantization of vibrational energy levels. Selection rules, IR spectra of diatomic molecules. Structural information derived from vibrational spectra, dissociation energies, vibration-rotation transitions in diatomics, harmonic oscillator, anharmonicity, centrifugal distortion, Vibration of polyatomic molecules, normal modes, combination, difference and hot bands, Fermi Resonance, Group frequencies. Effect of hydrogen bonding (inter- and intramolecular) on vibrational frequencies.

Raman spectroscopy: Light scattering and Raman effect, classical and quantum models for scattering, Stokes and anti-Stokes lines; their intensity difference, polarizability, selection rules, group theoretical treatment of vibrations, Effect of nuclear spin, Vibrational Raman spectra, rule of mutual exclusion for centrosymmetric molecules, polarized and depolarized Raman lines, resonance Raman scattering.

Applications of Group theory for molecular vibration, symmetry of group vibrations. Selection rules and applications to IR and Raman spectra.

UNIT – 5 **(10 hrs)**

Electronic Spectroscopy of molecules: Molecular orbitals and states, term symbols, selection rules, vibrational and rotational structures, Free Electron model, its application to electronic spectra of polyenes. Frank-Condon principle, electronic transitions, Beer Lambert's Law, dissociation and predissociation, photoelectron spectroscopy, dissociation and predissociation, calculation of heat of dissociation, Birge Sponer method, electronic spectroscopy of polyatomic molecules

Singlet and triplet states, Jablonski diagram, fluorescence and phosphorescence, Solvent and environmental effects, Fluorescence quenching, energy transfer and electron transfer, time domain lifetime measurements.

NMR: Expression for Hamiltonian/Energy - Zeeman interaction, torque exerted by a magnetic field on spins, equation, its solution and the physical picture of precession. Thermal equilibrium, Relaxation, chemical shift, shielding and deshielding, Karplus relationships, Bloch equations, the rotating frame, pulsed experiments, NOE, double irradiation, selective decoupling, double resonance, Polarisation transfer, Two-dimensional NMR, Solid state NMR, NQR, MRI

Recommended Text Books:

1. F. A. Cotton, Chemical Applications of Group theory, Wiley Eastern, Singapore, 2nd ed., 1992.

2. V. Ramakrishnan, M. S. Gopinathan, Group theory in Chemistry, Vishal Pub. New Delhi, 1996.

3. Alan Vincent, Molecular Symmetry and Group Theory: A Programmed Introduction to Chemical Applications, 2nd ed., Wiley, 2013.

4. Robert L. Carter, Molecular Symmetry and Group Theory, Wiley, 2009.

5. G. M. Barrow, Introduction to Molecular Spectroscopy, McGraw Hill, New York, 1962.

6. C. N. Banwell, Fundamentals of Molecular Spectroscopy, 4th ed., Tata McGraw Hill, 1996.

7. A. E. Derome, Modern NMR Techniques for Chemical Research, Pergamon Press, 1987.

8. D. H. Williams, I. Flemming, Spectroscopic Methods in Organic Chemistry, 4th ed., McGraw-Hill, 1985.

9. H. Gunther, NMR Spectroscopy, 2nd ed., John Wiley, 2005.

10. N. B. Colthup, L. H. Daly, S. E. Wiberley, Introduction to Infrared and Raman Spectroscopy, 3rd ed., 1982.

11. R. A. Alberty, Physical Chemistry 8th ed., Wiley, New York, 1994.

12. P. W. Atkins, Physical Chemistry 8th ed., W. H. Freeman, New York, 2006.

13. I. N. Levine, Molecular Spectroscopy, John Wiley & Sons.

14. J. M. Hollas, Modern Spectroscopy, John Wiley & Sons.

15. P. F. Bernath, Spectra of Atoms and Molecules, III Edn, Oxford University Press.

16. J. L. McHale Molecular Spectroscopy, Pearson Education.

17. W. W. Parson, Modern Optical Spectroscopy, Springer-Verlag.

18. Jack D. Graybeal, Molecular Spectroscopy, Mc Graw Hill International Editions

19. M.H. Levitt, Spin Dynamics, II edn.Wiley

20. James Keeler, Understanding NMR spectroscopy, II edn. Wiley

21. Joseph R. Lakowicz, Principles of Fluorescene Spectroscopy, 3rd Ed., Plenum Press, 2010.

CORE/LAB

CHE 10705

ADVANCED CHEMICAL SYNTHESIS AND SEPARATION LAB

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Acquire knowledge on safe laboratory practices of handling laboratory glassware, equipment and chemical reagents.	Knowledge
C.O.2: Plan and perform synthetic procedures, chromatographic separation and purification of organic compounds.	Understand
C.O.3: Separate organic compounds from the organic binary mixture and identify the functional group(s) present.	Analysis
C.O.4: Use software to Draw the structures and schemes of organic molecules and reactions.	Apply
C.O.5: Use Chemical Abstracts, Scopus, Organic Synthesis collective volumes on web etc. to search, analyse and collect chemical information.	Apply
C.O.6: Identify the cations in a mixture of unknown salts.	Analyse
C.O.7: Estimate the amount of a given metal ion by complexometric and cerimetric reactions.	Analyse
C.O.8: Synthesise metal complexes and characterize them by various physicochemical methods.	Apply
C.O.9: Record and interpret electronic spectrum of different metal complexes.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x		x	x	
C.O.2	x	x	x		x	x		x	x	
C.O.3	x	x		x		x		x	x	
C.O.4	x	x				x	x	x	x	

C.O.5	x	x			x	x		x	x	
C.O.1	x	x						x	x	
C.O.2	x	x		x				x	x	
C.O.3	x	x	x			x		x	x	
C.O.4	x	x				x	x	x	x	

UNIT – 1 **(48 hrs)**

Part I: General methods of separation and purification of Organic compounds such as 1) Solvent extraction 2) Thin layer chromatography and paper chromatography 3) column chromatography

Part II: Separation and identification of the components of organic binary mixtures.

Part III: Preparation of Organic compounds by multistep reactions, purification of products and characterisation using UV-Vis, FTIR and NMR.*

Part IV: Drawing the structures of organic molecules and reaction schemes by Proprietary and open source computer software. Use Chemical Abstracts, Scopus, Organic Synthesis collective volumes on web etc., to search, analyse and collect chemical information.

*Progress of the reactions should be followed by spectroscopic and chromatographic methods (UV-Vis, TLC, GC, HPLC, etc)

UNIT – 2 **(48 hrs)**

Reactions of titanium, vanadium, chromium, manganese, iron, cobalt, nickel and copper ions. Reactions of some less common metal ions (Tl, W, Mo, V, Zr, Th, U). The spot test technique for metal ions. Semimicro qualitative analysis of common and rare cations in a mixture.

Estimation of metal ions by complexometric and cerimetric titrations. Estimation of Mg, Ca, Mn, hardness of water.

Synthesis of inorganic complexes and their characterization by various physicochemical methods, such as IR, UV, Visible, NMR, magnetic susceptibility etc. Selection can be made from the following or any other complexes for which references are available in the literature.

Tris(oxalato)manganese(III)

Tetrapyridinesilver(II)peroxidisulphate

Tris(acetylacetonato) iron(III)

Bis(N,N-diethyldithiocarbamato)nitrosyliron(I)

Optical isomers of tris(ethylenediamine)cobalt(III)chloride

Nitropentamminecobalt(III) chloride

Tri(acetylacetonato)manganese(III)

Tris(thiourea) copper(I) sulphate

Phenyl lithium

Tetraphenyl lead

Ferrocene

Phosphonitrilic chloride

Anhydrous copper(II) nitrate

Interpretation of its electronic spectrum and calculation of Dq values.

Determination of crystal field splitting energy for certain ligands and construction of a part of the spectrochemical series.

Recommended Text Books:

1. A. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Vogel's Textbook of Practical Organic Chemistry, 5th ed., John Wiley, 1989.
2. D. L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Organic laboratory Techniques, 3rd ed., Saunders Golden Sunburst Series.
3. L. W. Harwood, C. J. Moody, Experimental Organic Chemistry-Principles and Practice, Blackwell Science Publications.
4. G. Pass, H. Sutcliffe. Practical Inorganic Chemistry 2nd ed., Chapman & Hill. 1974.
5. G. Marr, B. W. Rockett, Practical Inorganic Chemistry, Van Nostrand, 1972.

CORE/LAB

CHE 10706

OPEN ENDED LAB-III

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validating the hypothesis.

The students shall submit a project progress report

ELECTIVE

CHE 10707

SUPRAMOLECULAR CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Explain the structural features of any given supramolecular system	Analyze
C.O.2: Analyze the type of possible interactions in any given host guest assembly	Analyze
C.O.3: Predict the photochemical and Photophysical behavior in constrained media	Analyze
C.O.4: Analyze the change in electronic structure of the supramolecular systems based on the interaction with the host	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x									
C.O.2	x	x								
C.O.3		x			x					
C.O.4					x		x			

UNIT – 1 **(10 hrs)**

Structure, Preparation and Properties of: crown ethers, cryptates, cryptands, carcerands, calixarenes, cyclodextrins, fullerenes, dendrimers, rotaxanes, cucurbiturils, COF, MOF.

UNIT – 2 **(10 hrs)**

Noncovalent Interactions –Hydrogen bonding, π Effects, dipole interactions, Induced dipole interactions, Hydrophobic interactions. Solvent Effects, Thermodynamics of binding phenomena.

UNIT – 3 **(10 hrs)**

Molecular Recognition – Host guest interactions, Complementarity and Reorganization, large ion pairing component, hydrophobic component, hydrogen bond, π-component. Complex Architectures – Self-assembly, coordination, hydrogen bonding.

UNIT – 4 **(10 hrs)**

Photochemistry in constrained media- photophysical, photochemical processes, energy transfer, electron transfer. Effect of structural features and interactions on energy levels.

UNIT – 5 **(8 hrs)**

Applications – photocatalysis, water splitting, solar cell, CO2 reduction, drug delivery, sensors, gas separation and storage.

Recommended Text Books:

1. Jonathan W. Steed, Jerry L. Atwood, Supramolecular Chemistry, Wiley, 2013.
2. J. M. Lehn, Supramolecular Chemistry: Concepts and Perspectives, Wiley, 1995
3. E.V. Ansyln, D. A. Dougherty, Modern Physical Organic Chemistry, University Press, 2006.
4. P. Klan and J. Wirz, Photochemistry of Organic Compounds,
5. Modern Molecular Photochemistry of Organic Molecules, Nicholas J. Turro, V. Ramamurthy, J.C. Scaiano,
6. Christian S. Diercks, Markus J. Kalmutzki, and Omar M. Yaghi, Introduction to Reticular Chemistry: Metal-Organic Frameworks and Covalent Organic Frameworks, Wiley, 2019.
7. Shengqian Ma, Jason A Perman, Elaboration and Applications of Metal-organic Frameworks, World Press, 2018.

ELECTIVE

CHE 10708

GREEN CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Apply the concepts of green chemistry for a given chemical process	Analyze
C.O.2: Describe the various green materials which can be used as alternatives	Understand
C.O.3: Describe the various green technologies which can be used as alternatives	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x		x							
C.O.2	x		x							x
C.O.3	x		x							x

UNIT – 1 **(10 hrs)**

Green Chemistry and industry, waste minimization, E factor and atom economy, Reduction of- material use, energy, risk and hazards. Sustainable use of- chemical feedstocks, water, energy. LCA methodology, Renewables as Chemical Feedstocks and Biocatalysis, Process Intensification for Green Chemistry.

UNIT – 2 **(10 hrs)**

Catalysis in green chemistry – Homogenous catalysis , Heterogeneous catalysis, metal catalysts, metal oxide catalyst, metal complexes, Solid Acid Catalysts - Concepts and applications, Zeolite, Heteropolyacid, Ion-exchange resins as solid acid catalysts, Kvaerner Process, Nafion /silica nanocomposites, Haldor–Topsoe alkylation process to high-octane fuels. Micelle-templated Silica as Catalysts in Green Chemistry - Synthesis of micelle templated materials, Catalytic Applications - Oxidation catalysis, Base catalysis, Enantioselective catalysis.

UNIT – 3 **(10 hrs)**

Phase-transfer Catalysis(PTC) - Classical PTC Reactions, Nucleophilic aliphatic and aromatic Substitutions, Phase-transfer catalysis elimination and isomerisation reactions, Base-promoted alkylation and arylation, Inverse PTC, Phase-transfer Catalysis in Polymerisation, Applications of PTC in Analytical Chemistry. Biocatalysis - antibody catalysts, Enzyme Catalysts, Biomimetic catalysts, Chemical Production by Biocatalysis, Bulk chemicals, Pharmaceuticals, Flavour and fragrance compounds, Carbohydrates, Polymers, Biocatalysis in supercritical CO_2, Biocatalysis in waste treatment.

UNIT – 4 **(10 hrs)**

Specific green technologies - hydrogen peroxide in waste minimization, waste minimization in pharmaceutical process development, supercritical carbondioxide as an environmentally benign reaction medium for chemical synthesis, reduction of volatile organic compound emission during spray painting.Extraction of natural product with super-heated water, Synthesis at organic – water interface, Envirocats, applications of microwaves for environmentally benign organic chemistry, Sonochemistry – Concept, application in chemical synthesis.

UNIT – 5 **(8 hrs)**

Photochemistry - Photons as Clean Reagents, Reduced usage of reagents, Lower reaction temperatures, Control of selectivity, Photochemical reactions forindustry, General Problems with Photochemical Processes, Specialized photochemical reactors and process technology, Photochemical reactors, Light sources, Artificial Photosynthesis for small molecule conversions. Green Nanoscience - Photocatalysis by Nanostructured TiO_2-based Semiconductors, Formation of Nanoparticles Assisted by Ionic Liquids, Nanoencapsulation for

Process Intensification, Nanophase Inorganic Materials, Nanomaterials from Biobased Amphiphiles.

Recommended Text Books:

1. Paul T. Anastas and John C. Warner, *Green Chemistry: Theory and Practice*, Oxford University Press, 1998.
2. J. Clark, D. Mcquarrie, *Hand Book of green Chemistry and technology*, Blackwell science, 2002.
3. Mike Lancaster, *Green Chemistry: An Introductory Text*, RSC, 2007.
4. P. T. Anastas, T. C. Williamsons, *Green Chemistry – Designing Chemistry for the Environment*, ACS, 1994.
5. V. K. Ahluwalia, M. Kidwai, *New Trends in Green Chemistry*, 2nd edition, Anamaya Publishers, 2006.
6. V. K. Ahluwalia, *Green Chemistry*, Narosa Publishing House, 2011.
7. Alvise Perosa, Maurizio Selva, *Handbook of Green Chemistry- Volume 8- Green Nanoscience*, Wiley-VCH, 2012.

ELECTIVE

CHE 10709

POLYMER CHEMISTRY

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Recognise the concept of macromolecules and describe the classification, synthesis and process technologies involved in common polymers.	Understand
C.O.2: Analyse the kinetics and mechanism involved in different types of polymerization	Analyse
C.O.3: Apply the concepts of stereochemical aspects and analyse the conformation and configuration of polymers	Analyse
C.O.4: Apply different characterisation techniques to identify polymers.	Apply
C.O.5: Explain the synthesis, structure and applications of industrial polymers.	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x		x						x	
C.O.2					x					
C.O.3	x	x							x	x
C.O.4						x	x			
C.O.5						x	x			

UNIT – 1 **(10 hrs)**

History of Polymer Science. Concept of macromolecules, Principle of duality, Integration of molecular character and material character. Molecular design, synthesis and process technologies. Nomenclature and Classification. Raw

Material sources of polymers. Natural gas, coal and petroleum. Monomers and polymers derived from natural gas. Petroleum and petrochemicals. Monomers and polymers derived from ethylene and propylene. Monomers and polymers derived from C4 and C5 Systems and BTX fraction. Acetylene as a source of monomers.

UNIT – 2 **(10 hrs)**

Polymerization processes. Free radical addition polymerization. Kinetics and mechanism. Chain transfer. Molecular weight distribution and molecular weight control. Cationic and anionic polymerization. Polymerization without termination. Living polymers. Step Growth polymerization. Kinetics andmechanism. Linear Vs cyclic polymerization, Group Transfer, metathesis and ring opening polymerization. Copolymerization. The copolymerization equation, Q-e scheme, Gelation and Crosslinking. Copolymer composition drift. Polymerization techniques. Bulk Solution, melt, suspension, emulsion and dispersion techniques.

UNIT – 3 **(10 hrs)**

Polymer Stereochemistry. Organizational features of polymer chains. Configuration and conformation, Tacticity, Repeating units with more than one asymmetric center. Chiral polymers – main chain and side chain. Stereoregular polymers. Manipulation of polymerization processes. Zeigler-Natta and Kaminsky routes. Coordination polymerization. Metallocene and Metal oxide catalysts.

UNIT – 4 **(10 hrs)**

Polymer Characterization. Molecular weights. Concept of average molecular weights, Determination of molecular weights. GPC and Light scatteringtechniques. Molecular weight distribution. Crystalline and amorphous states. Glassy and Rubbery States. Glass transition and crystalline melting. Spherullites and Lammellae. Degree of Crystallinity, Thermal analysis of polymers. TG/DTG, DTA/DSC, Spectroscopy of polymers. Microstructure determination by IR, Raman, UV, NMR and MS techniques. Solid State NMR and polymer stereochemistry.

UNIT – 5 **(8 hrs)**

Industrial polymers. Synthesis, Structure and applications. Polyethylene, polypropylene, polystyrene. PVC, PVA, PAN, PA. Poly(vinyl carbazole), poly(vinyl imidazole). PMMA and related polymers. Flourine containingpolymers. Reaction polymers. Polyamides, polyesters. Epoxides, polyurethanes, polycarbonates, phenolics, PEEK, Silicone polymers. Reactions of polymers. Polymers as aids in Organic Synthesis. Polymeric Reagents, Catalysts, Substrates, Liquid Crystalline polymers. Main chain and side chain liquid crystalline polymers.

Recommended Text Books:

1. Billmayer, F.W. Textbook of Polymer Science. 3rd Ed., Wiley. N.Y.1991.
2. Cowie, J.M.G. Polymers: Physics and Chemistry of Modern Materials. Blackie. London,1992.
3. Young, R.J. Principles of Polymer Science, 3rd Ed., Chapman and Hall. N.Y.1991.
4. Flory, P.J. A Text Book of Polymer Science. Cornell University Press. Ithacka, 1953.
5. Ullrich, F. Industrial Polymers, Kluwer, N.Y.1993.
6. Elias, H.G. Macromolecules, Vol. I & II, Academic, N.Y.1991.
7. Brydson, J.A. Polymer chemistry of Plastics and Rubbers, ILIFFE Books Ltd., London,1966

MOOC ELECTIVE

CHE 10710

BONDS AND BANDS IN SOLIDS

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe the theoretical aspects of solid state structure	Understand
C.O.2: Correlate the structural aspects to electronic properties	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x								
C.O.2	x	x								

UNIT – 1 **(6 hrs)**

One-electron Hamiltonian after B.O and SCF approx., Bonding in Hn System, n=2,3….N

UNIT – 2 **(6 hrs)**

Bloch’s theorem, Energy bands, Metal, Insulator, Semi-conductors; Brillouin Zones, Different Schemes, Density of States, Extension to p-orbitals, square lattices etc

UNIT – 3 **(6 hrs)**

Peiperl’s instability, Nearly Free Electron Model, Fermi Surface, Density of States, Effective Mass etc.,, Failures of MO and Band Theories, Beyond energy band , Interacting electron models and Kinetic exchange

UNIT – 4 **(6 hrs)**

Energy levels in interacting models, Excitons; Lattice, vibrations, Acoustic modes, optic modes etc.,

UNIT – 5 **(8 hrs)**
Phonon Photon interaction, thermal properties of insulators

Recommended Text Books:

1. C. Kittel, "Introduction to Solid State Physics"
2. J. M. Ziman, "Principles of the Theory of Solids"
3. N.W. Ashcroft and N.D. Mermin, "Solid State Physics"

SWAYAM

Prof. S. Ramashesha

IISc,Bangalore

AUDIT

CHE 10711

PROFESSIONAL AND CAREER DEVELOPMENT IN CHEMISTRY

Credit 0 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Skills on subject specific pedagogy, soft skills, ICT tools, research proposal writing, finding scholarships and software for chemistry	Create

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1									X	X

UNIT – 1 **(32 hrs)**

Soft Skills – Powerpoint, Word, Exel, Reference management software- Mendeley, Origin, Veusz, Research Proposal Writing – Literature review, Components of proposals, ICT – Google Classroom, Moodle, Class Recording, Teach Infinity, OBS, edmondo, QUIZZ Quiz, Document scanner., Subject specific pedagogy – Molecular model kit, ChemDraw, ChemSketch, Finding International Scholarships- MEXT, DAAD, EURAXESS, J-Rec, Funding through embassy

Lab safety, research ethics, research methodology.

Recommended Text Books:

1. John M. Swales & Christine B. Feak, Academic Writing for Graduate Students 3rd Edition, Michigan Publishing, 2012
2. Stephen Bailey, Academic Writing, A Handbook for International Student, 5^{th} Edition, Routledge, Taylor & Francis, 2018

CORE

CHE 10801

Inorganic Chemistry – IV

(CHEMISTRY OF d- AND f-BLOCK ELEMENTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe and explain the structure, bonding and magnetism in metal complexes using crystal field theory.	Analyse
C.O.2: Describe various metal-ligand interactions in terms of sigma- and pi-bonding.	Analyse
C.O.3: Identify various d-d transitions and interpret the electronic spectra of any given transition metal complex.	Evaluate
C.O.4: Interpret the ESR spectra of any given transition metal complex.	Evaluate
C.O.5: Explain the stability of metal complexes, their reactivity, and the mechanisms of ligand substitution and redox reactions.	Evaluate
C.O.6: Interpret the Mossbauer spectra of iron complexes.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x			x			x		
C.O.3	x	x				x		x		
C.O.4	x	x				x		x		
C.O.5	x	x			x			x		
C.O.6	x	x				x		x		

UNIT – 1 **(6 hrs)**

Crystal-field theory, d-orbital splitting in octahedral, tetrahedral, square planar, trigonal bipyramidal, trigonal planar and linear geometries, crystal field stabilization energy, effect of pairing energy.

Molecular Orbital Theory: construction of molecular orbital diagrams using group theory, qualitative MO diagrams for octahedral, tetrahedral and square planar complexes, effect of π-bonding, experimental evidence for π-bonding, spectrochemical series.

UNIT – 2 **(10 hrs)**

Microstates, Atomic term symbols Free ion terms for dn configuration, Splitting of terms in octahedral and tetrahedral octahedral fields, Correlation diagram ford^2 configuration in octahedral geometry, d-d transitions, Selection rules for electronic transitions.

Orgel diagram – splittings for d^1, d^9, high spin d^4, d^6, splittings for high spin d^2, d^3, d^8 and d^7

Calculation of Dq, B and β

Tanabe Sugano diagrams – splittings for low spin d^n systems

Electronic Spectral interpretation of some coordination compounds

Consequence of Jahn Teller effect on the electronic spectra of coordination compounds

Charge transfer spectra, Electronic spectra of lanthanide and actinide complexes

UNIT – 3 **(6 hrs)**

Magnetism: brief review of different types of magnetic behaviours, spin-orbit coupling, quenching of orbital angular moments in crystal field, spin-only formula, correlation of μ_s and μ_{eff} values, magnetic moments of T terms and A, E terms, temperature independence paramagnetism, magnetic properties of lanthanides and actinides.

UNIT – 4 **(12 hrs)**

Electronic paramagnetic resonance spectroscopy: Electronic Zeeman effect, Zeeman Hamiltonian and EPR transition energy. Presentation of spectra. The effects of electron Zeeman, nuclear Zeeman and electron nuclear hyperfine terms in the Hamiltonian on the energy of the hydrogen atom. Second order effect. Hyperfine splittings in isotropic systems, spin polarization mechanism and McConnell's relations Anisotropy in g-value, EPR of triplet states, zero field splitting, Kramer's rule, survey of EPR spectra of first row transition metal ion complexes.

Mossbauer spectroscopy- Principles and applications to coordination compounds.

UNIT – 5 **(14 hrs)**

Reaction Mechanism: Thermodynamic and kinetic consideration, formation constant and rate constant, inert and labile complexes, factors affecting the stability and lability of complexes.

Ligand substitution in octahedral complexes, mechanism of substitution reactions in octahedral complexes, dissociative, associative and interchange mechanism, energy profile of reactions, acid and base hydrolysis, factors affecting the rate of substitution reactions in octahedral complexes.

Ligand substitution in square planar complexes, mechanism of substitution reactions in square planar complexes, energy profile of reactions, the trans effect and its applications, theories for explaining trans effect, factors affecting the rate of substitution reactions in square planar complexes.

Electron Transfer Reactions: inner sphere and outer sphere mechanism, Marcus theory, photochemical reactions

Recommended Text Books:

6. G.L. Miessler, P.J. Fischer, D.A. Tarr, Inorganic Chemistry, 5th ed., Pearson, 2014.
7. F. A. Cotton, G. Wilkinson, C. A, Murillo, M. Bochmann Advanced Inorganic Chemistry, 6th ed., Wiley-Interscience: New York, 1999.
8. J.E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.

9. J. W. Steed, J. L. Atwood, Supramolecular Chemistry, 2^{nd} ed., John Wiley & Sons Ltd., 2009.

10. D. F. Shriver, P. W. Atkins, C. H. Langford, Inorganic Chemistry, 3^{rd} ed., ELBS, 1999.

11. B. Douglas, D. McDaniel, J. Alexander, Concepts and Models of Inorganic Chemistry, 3^{rd} ed., John Wiley and Sons, 1994.

12. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, 2^{nd} ed., BH, 1997.

13. R. S.Drago, Physical Methods for Chemists, 2^{nd} ed., Saunders College Publishing, 1992.

14. C. E. Housecroft, A. G. Sharpe, Inorganic Chemistry, 5^{th} ed., Pearson, 2018.

15. W. L. Jolly, Modern Inorganic Chemistry, 2^{nd} ed., McGraw-Hill, New York, 1991.

16. , Elements of Chemical Thermodynamics, Addison Wesley, 2^{nd} Edn, 2013.

CORE

CHE 10802

ORGANIC CHEMISTRY -II

(REACTIONS, REAGENTS AND SYNTHESIS)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Interpret the differences in reactivity of various reducing and oxidizing agents with mechanistic illustrations.	Apply
C.O.2: Analyse the reagents and conditions for the synthesis of specific target molecules.	Analyse
C.O.3: Describe strategies for the stereospecific/stereo selective organic transformations towards chiral target molecules.	Apply
C.O.4: Construct a synthetic pathway for simple to complex organic molecules by retrosynthetic approach.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x									
C.O.2			x					x		
C.O.3			x					x		
C.O.4			x					x		

UNIT – 1 **(14 hrs)**

Reagents for oxidation and reduction: Chromium reagents, activated DMSO, osmium tetroxide, selenium dioxide, singlet oxygen, peracids, hydrogen peroxide, periodic acid, lead tetraacetate, ozonolysis, Woodward and Prevost hydroxylation, Wacker process, Oppenauer oxidation, Sharpless, Shi andJacobsen asymmetric epoxidations. Catalytic hydrogenations (heterogeneous-Palladium/Platinum/Rhodium and Nickel, homogeneous-Wilkinson), metal hydride reduction- $LiAlH_4$, DIBAL-H, Red-Al, $NaBH_4$ and $NaCNBH_3$. Selectrides, trialkylsilanes and trialkyl stannane. Birch reduction, hydrazine and diimide reduction. Meerwein-Ponndorf-Verley reaction, Enzymatic reduction using Baker’s yeast..

UNIT – 2 **(12 hrs)**

Synthetic applications of organometallic and organo-nonmetallic reagents: Hydorboration reactions, Sakurai allylation, Gilman’s reagent, Ullmann and Glaser coupling reactions. Suzuki coupling, Sonogashira coupling, Heck reaction, Buchwald–Hartwig coupling, Negishi coupling and Stille coupling. Metathesis processes of electrophilic carbene complexes (first- and second-generation Grubbs catalyst), ROMP, Dötz reaction and methylenation of carbonyls.

Reagents such as NBS, DCC, DMAP, DEAD, DDQ. Phase transfer catalysts.

Chemistry of Nucleophilic Heterocyclic Carbenes (NHCs), multicomponent reactions such as Ugi reaction, Passerini reaction, Biginelli reaction. Click reaction.

UNIT – 3 **(12 hrs)**

Chemistry of carbonyl compounds: Reactivity of carbonyl groups in aldehydes, ketones, carboxylic acids, esters, acyl halides and amides. Substitution at carbonyl carbon, mechanisms of ester hydrolysis, substitution at α-carbon, aldol and related reactions. Grignard reaction, Reformatsky reaction, Claisen, Darzen, Dieckmann, Knoevenagel and Stobbe condensations. Perkin, Prins, Mannich, Stork-enamine reactions. Conjugate additions, Michael additions and Robinson annulation. Favorskii reaction, Julia olefination, Peterson olefination.
Reaction with phosphorous and sulfur ylides.

UNIT – 4 **(12 hrs)**

Asymmetric Synthesis: Introduction to asymmetric synthesis, principle, general strategies, chiral pool strategy, chiral auxiliaries, chiral reagents – Binol derivatives of $LiAlH_4$, chiral catalysts – CBS catalyst. Stereospecific and stereoselective synthesis, determination of enantiomeric and diastereomeric excess.

Stereoselective nucleophilic additions to acyclic carbonyl groups-Cram's Rule, Felkin-Ahn Model, Effect of chelation on selectivity.

UNIT – 5 **(14 hrs)**

Synthesis planning and analysis: Convergent, divergent and parallel synthesis. Protecting groups- protection and deprotection of hydroxyl, carboxylic acids, carbonyls in aldehydes and ketones, amines, alkenes and alkynes. Chemo- & regioselective protection and deprotection. Functional group equivalents, reversal of reactivity (Umpolung). Disconnection approach-introduction to retrosynthesis, basic principles, synthons, and synthetic equivalents. Monofunctional and bifunctional disconnection, One group C-X and two group C-X disconnections, one group C-C and two group C-C disconnections. Retrosynthesis of longifoline, Corey lactone, Djerassi - Prelog lactone and D-luciferin.

Recommended Text Books:

1. M. B. Smith, Organic Synthesis, 2nd ed., McGraw-Hill, 2000.
2. M. B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 7th ed., Wiley, 2013.
3. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.

4. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.
5. P. S. Kalsi, Stereochemistry, Conformation and Mechanism, 9th ed., New Age Publications, 2017.
6. T. Tsuji, Transition Metal Reagents and Catalysts: Innovations in Organic Synthesis, John Wiley & Sons, 2000.
7. S. Warren, Organic Synthesis: The Disconnection Approach, 2nd ed., John Wiley, 2008.
8. E. Robert, Gawley, J. Aube, Principles of Asymmetric Synthesis, 2nd ed., Elsevier, 2012.
9. G. L. D. Krupadanam, Fundamentals of Asymmetric Synthesis, 1st ed., CRC press, 2014.
10. T.W. Greene, P. G. M. Wuts, Protecting Groups in Organic Synthesis, 2nd ed., John Wiley, 1991.
11. H. R. Crabtree, The Organometallic Chemistry of the Transition Metals, 6th ed., John Wiley & Sons, 2014.
12. S. D. Burke, R. L. Danheiser, Handbook of Reagents for Organic Synthesis, John Wiley & Sons, 1999.

CORE

CHE 10803

ORGANIC CHEMISTRY -III

(SPECTROSCOPY OF ORGANIC COMPOUNDS)

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Identify structures of unknown organic compounds using hyphenated techniques and spectral library matching.	Apply
C.O.2: Identify structures of unknown organic compounds based on the data from UV-Vis, IR, Mass Spectrometry ^{1}HNMR and ^{13}CNMR spectroscopy.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x	x	
C.O.2	x	x						x	x	

UNIT – 1 **(6 hrs)**

Study of Mass Spectrometry applied to organic molecular systems

Elemental analysis, empirical formula, molecular formula, Molecular mass, nominal mass, Exact mass, Index of hydrogen deficiency.

The technique of Mass Spectrometry: Molecular ion, ion production methods (EI). Soft ionization methods: FAB, CA, MALDI, PD, Field desorption electrospray ionization, HRMS and formula mass, LC-MS, GC-MS. MS- MS Mass spectra of chemical classes and its correlation with structure: Fragmentation patterns, nitrogen and ring rules, Rule of thirteen, McLafferty rearrangement.

UNIT – 2 **(6 hrs)**

Study of Ultraviolet-Visible Absorption and Emission and Chirooptical Spectroscopy applied to organic molecular systems

Energy levels and selection rules, Woodward-Fieser and Fieser-Kuhn rules, estimation of λmax of substituted aromatic ketones, aldehydes and acids. Spectral correlation with structure: Influence of substituents, conjugation, Intramolecular Charge transfer, Solvent effect

Fluorescence Spectroscopy. Excitation and Emission Spectra. Fluorescence Quantum Yield and Lifetime. Spectral correlation with structure: Influence of substituents, ring size, strain and conjugation, Intramolecular Charge transfer, Intramolecular proton transfer, Solvent effect

Chirooptical Spectroscopy: Introduction and applications of ORD, CD, Octant rule, axial haloketone rule, Cotton effect.

UNIT – 3 **(6 hrs)**

Study of Infrared Spectroscopy applied to organic molecular systems

Fundamental vibrations, overtones, Fermi Resonance, Hot bands, combination bands

Spectral correlation with structure: Characteristic regions of the spectrum. Influence of substituents, ring size, hydrogen bonding, vibrational coupling, hybridization and field effect on frequency.

IR spectra of chemical classes including amino acids and its correlation with structure

UNIT – 4 **(10 hrs)**

Study of NMR spectroscopy applied to organic molecular systems

The NMR instrumentation and Experiment: Magnetic nuclei with special reference to 1H and 13C nuclei. Chemical shift and shielding/deshielding, relaxation processes, chemical and magnetic non-equivalence, local diamagnetic shielding and magnetic anisotropy. Proton and 13C NMR scales, characteristics of 13C as a nucleus.

Spin-spin splitting, AX, AX2, AX3, A2X3, AB, ABC, AMX type coupling, First order and non-first order spectra, Pascal's triangle, coupling constant, mechanism of coupling, Karplus curve, quadrupole broadening and decoupling, diastereomeric protons, virtual coupling, long range coupling effects, NOE, coupling with other nuclei.

Simplification non-first order spectra to first order spectra, shift reagents-mechanism of action, spin decoupling and double resonance, Chemical shifts and homonuclear/heteronuclear couplings, the basis of heteronuclear decoupling.

Polarization transfer. Selective Population Inversion (qualitative description only), DEPT, sensitivity enhancement and spectral editing. 2D NMR and COSY, HMQC, HMBC.

UNIT – 5 **(4 hrs)**

Identification of structures of unknown organic compounds using hyphenated techniques and Spectral library matching.

Identification of structures of unknown organic compounds based on the data from UV-Vis, IR, Mass, 1HNMR and 13CNMR spectroscopy.

Recommended Text Books:

1. D. L. Pavia, G. M. Lampman, G. S. Kriz, J. R. Vyvyan, Introduction to Spectroscopy: A Guide for Students of Organic Chemistry, Indian ed., Brooks/Cole Cengage Learning, 2007.
2. Atta-Ur-Rahman, M. I. Choudhary, Solving Problems with NMR Specroscopy, Academic Press, New York, 1996.
3. L. D. Field; S. Sternhell, J. R. Kalman; Organic Structures from Spectra, 4th ed., Wiley 2008.
4. R. S. Drago, Physical Methods for Chemist, Saunders,1992.

5. C. N. Banwell, E. M. McCash, Fundamentals of Molecular Spectroscopy, 4th ed., McGrawHill, 1994.
6. D. F. Taber, Organic Spectroscopic Structure Determination, A Problem Based Learning Approach, Oxford University Press, 2009.
7. R. M. Silverstein, G. C. Bassler, T. C. Morril, Spectroscopic Identification of Organic Compounds, John Wiley, 1991.
8. D. H. Williams, I. Fleming, Spectroscopic Methods in Organic Chemistry, Tata McGraw Hill, 1988.
9. W. Kemp, Organic Spectroscopy, 2nd ed., ELBS-Macmillan, 1987.
10. F. Bernath, Spectra of Atoms and Molecules, 2nd ed., Oxford University Press, 2005.
11. E. B. Wilson, Jr., J. C. Decius, P. C. Cross, Molecular Vibrations: The Theory of Infrared and Raman Spectra, Dover Publications, 1980.
12. A. Weil, J. R. Bolton, Electron Paramagnetic Resonance: Elementary Theoryand Practical Applications, 2nd ed., Wiley Interscience, John Wiley & Sons, Inc.,2007.
13. C. P. Slichter, Principles of Magnetic Resonance, 3rd ed., Springer-Verlag, 1990.
14. H. Gunther, NMR Sprectroscopy: Basic Principles, Concepts and Applications in Chemistry, 3rd ed., Wiley- VCH, 2013.
15. Spectral data bases (RIO DB of AIST, for example).

CORE

CHE 10804

PHYSICAL CHEMISTRY- III

(STATISTICAL AND NON-EQUILIBRIUM THERMODYNAMICS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Explain the different types of statistics and calculate the thermodynamic probability of any given thermodynamic system.	Analyse
C.O. 2: Calculate the partition function and thermodynamic properties from spectroscopic data.	Apply
C.O. 3: Apply the principles of statistical thermodynamics to ideal gases, solids and metals.	Apply
C.O. 4: Explain the basics of transport phenomena's viz., Osmosis, biological motors and electro kinetic effects.	Understand
C.O. 5: Derive expression for entropy production for physical and chemical processes	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X	X			X					
C.O.2	X	X			X					
C.O.3	X	X			X					
C.O.4	X	X			X					
C.O.5	X	X			X					

UNIT – 1 **(8 hrs)**

Kinetic Theory of gases, Maxwell Distribution of velocity, Boltzmann distribution, Types of molecular velocities- r.m.s, most probable and mean velocity, Molecular Collisions, Mean free path, Transport properties- Diffusion, effusion, Viscosity, Thermal conductivity.

Thermodynamic probability, microstate and macrostate, entropy andprobability, most probable distribution, residual entropy and its calculation. Ensembles, Maxwell - Boltzmann statistics.

UNIT – 2 **(10 hrs)**

Partition function and its relation to thermodynamic properties, Translational, rotational and Vibrational partition function. Molecular partition function for delocalized systems, calculation of equilibrium constant using partition functions. Heat capacity of gases, Anomalous heat capacity of H_2, Heat capacity of solids: Dulong - Petits law, Einstein's theory and its modification, Debye's theory of heat capacity of solids.

UNIT – 3 **(10 hrs)**

Quantum statistics, Bose - Einstein statistics, Fermi - Dirac statistics, Comparison of Maxell - Boltzman, Bose=- Einstein and Fermi - Dirac Statistics, Dilute Systems. Application of Bose -Einstein Statistics, Gas degeneration, Application to liquid helium, Bose Einstein Condensation. Application of Fermi -Dirac Statistics to electrons in metals, Extreme Gas Degeneration, Electron gas in metals and its contribution to pressure and heat capacity.

UNIT – 4 **(10 hrs)**

Partition function for systems of dependent particles, Configurational integral and configurational partition function. Imperfect gas, van der Waals equation and Virial equation of state, Evaluation of the first virial coefficient. Condensed state, Cluster integrals, Communal entropy.

UNIT – 5 **(10 hrs)**

Linear Non-equilibrium thermodynamics- General theory, Local entropy production, balance equation for concentration. Energy conservation in open systems. Entropy balance equation. Forces and Fluxes, Steady state and local equilibrium conditions. Linear phenomenological laws. Phenomenological coefficient, Systems with heat, matter and electrical transport, Onsager Reciprocal relation, Application to Diffusion -Thermal diffusion, Thermal Osmosis and electrokinetic effects, Soret Coefficient, Seebeck effect.

Recommended Text Books:

1. F.W. Sears, Introductions to Thermodynamics, Kinetic Theory of Gases and Statistical Mechanics, Addision Wesley Pub. Cambridge, 1998.
2. F.C. Andrews, Equilibrium to Statistical Mechanics, John Wiley, New York, 2002.
3. L.K. Nash, Statistical Thermodynamics, Addison Wesley, New York, 1999.
4. P. W. Atkins, J. de Paula, Physical Chemistry 8th ed., 9th edn. Wiley, New York, 2006
5. D. A. McQuarrie, Physical Chemistry- A Molecular Approach, South Asian Edn., 2008.
6. M. Dole, Introduction to Statistical Thermodynamics, Prentice Hall, London, 1997.
7. J. Kestin, J.R. Dorfman, A Course in Statistical Thermodynamics, Academic press, 1971.
8. D. A. McQuarrie, Statistical Thermodynamics, South Asian Edn., 2008.
9. I. Prigogine, Introduction to Thermodynamic Irreversible Processes, 3rd ed.,Wiley Interscience, 1968.
10. S. R. de Groot, P. Mazur, Non-equilibrium Thermodynamics, Dover Publications, 2011.
11. G. Lebon, D. Jou, J. Casas, Understanding Non-equilibrium Thermodynamics, Springer. 2008.
12. S. Kjelstrup, D. Bedeaux, E. Johannessen, J. Gross, Non-Equilibrium Thermodynamics for Engineers: Second Edition, World Scientific Publishing Company, 2017.
13. D. Kondepudi and I. Prigogine, Modern Thermodynamics: From Heat Engines to dissipative Structures, Wiley, New York.

CORE

CHE 10805

THEORETICAL CHEMISTRY-III

(CHEMICAL BONDING AND COMPUTATIONAL CHEMISTRY)

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Explain the quantum mechanical nature of the chemical bond.	Understand
C.O.2: Account for the basic principles and concepts of molecular orbital theory and valence bond theory using quantum mechanical principles.	Apply
C.O.3: Describe quantum mechanically the chemical bonding of any given di- and tri- atomic molecules with molecular orbital theory and valence bond theory.	Analyze
C.O.4: Describe the main similarities and differences between theoretical approaches and identify advantages and disadvantages for modelling various chemical problems.	Apply
C.O.5: Use computational chemistry software to perform and interpret electronic structure calculations.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x						x		
C.O.3	x	x						x		
C.O.4	x	x			x	x	x	x		
C.O. 5	x	x			x		x	x	x	

UNIT – 1 **(8 hrs)**

Chemical boning, Born Oppenheimer approximation, Valence bond method. Comparison of VB and MO method, LCAO approximation, calculation of energy

levels from wave functions, application to diatomic molecules such as, H_2^+, H_2. Concept of σ, σ*, π, π* orbitals and their characteristics, hybrid orbitals, calculation of coefficients of AO used in sp, sp^2 and sp^3 hybrid orbitals, interpretation of geometry, Valence bond model of H_2, Hybridisation of H_2O,
BF_3, NH_3 and CH_4

UNIT – 2 **(6 hrs)**

Pi bonding in simple molecules, HMO method for linear conjugated hydrocarbons, linear, cyclic, polycyclic, heterocyclic; ethylene, 1,3-butadiene,allyl radical, cation and anion, aromatic hydrocarbons, cyclopropenyl systems, cyclobutadiene, benzene, naphthalene, thiophene. calculation of charge
distribution, bond orders and reactivity.

UNIT – 3 **(6 hrs)**

Tools and philosophy of computational chemistry. potential energy surface - local minima, global minima, saddle point and transition states, geometry optimization-stationary points.

UNIT – 4 **(6 hrs)**

Basis sets, Slater and Gaussian functions, classification of basis sets - minimal, double zeta, triple zeta, split valence, polarization and diffuse basis sets, contracted basis sets, Pople style basis sets and their nomenclature, correlation consistent basis sets.

SCF methods, semiempirical, ab initio, electron correlations, post-Hartree-Fock methods and density functional theory.

UNIT – 5 **(6 hrs)**

Molecular structure, internal coordinates, Cartesian coordinates, geometry optimization, frequency analysis, partial charge, MO, Conformational analysis of ethane and butane

calculation of some simple chemical problems using computational chemistry programme packages

Recommended Text Books:

1. J. P. Lowe, Quantum Chemistry, 3rd ed., Academic Press, New York, 2008.
2. F. Jensen, Introduction to Computational Chemistry, 2nd ed., Wiley, New York, 2009.
3. R. Leach, Molecular Modeling, Principles and Applications, 2nd ed., Pearson Education, London, 2001.
4. A. K. Chandra, Introduction to Quantum Chemistry, 4th ed., Tata McGraw-Hill, 1994.
5. L. Pauling, E. B. Wilson, Introduction to Quantum Mechanics, McGraw-Hill, 1935.
6. A. Szabo, N. S. Ostlund, Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Book ed., Mc.Graw-Hill, New York, 1982.
7. T. A. Albright, J. K. Burdett, M.-H. Whangbo, Orbital Interactions in Chemistry, 2nd ed., John Wiley and Sons, Inc., Hoboken, New Jersey, 2013.

CORE/LAB

CHE 10806

ADVANCED PHYSICAL CHEMISTRY LAB-II

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Operate various sophisticated instruments.	Apply
C.O.2: Perform experiments based on various laws of physical chemistry.	Apply
C.O.3: I the results obtained from various experiments.	Analyse
C.O.4: Calculate the unknown concentration of the given solution based on the results obtained from the experiment.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	
C.O.2	x	x				x		x	x	
C.O.3	x	x				x		x	x	
C.O.4	x	x		x				x	x	

UNIT – 1 **(96 hrs)**

i. Molecular weight determination by cryoscopic methods, Formula of complexes.
ii. Phase diagrams: Two component liquid–liquid and solid-liquid systems. Three component liquid-liquid systems.
iii. Determination of transition temperature, molecular weight determination.
iv. Refractometry: Variation of refractive index with composition, formula of complexes.
v. Chemical Kinetics: Acid and base catalysed hydrolysis of esters,

vi. Dependence of temperature and ionic strength on the rate of reactions, Hydrolysis of p-nitrophenyl acetate using spectrophotometry.

vii. Ostwald Viscometer: Viscosity of liquid and liquid mixtures.

viii. Conductometry: Cell constant, conductivity of a weak-acid, solubility of a sparingly soluble salt, conductometric titrations. Determination of critical micelle concentration of colloids.

ix. Poteniometry: Measurement of electrode potentials, activity coefficients and potentiometric titrations, pH metric titrations.

x. Adsorption: Checking the validity of Freundlich and Langmuir adsorption and determination of unknown concentration.

xi. Spectrophotometry: Checking the validity of beer Lambert's law and determination of unknown concentration.

xii. Demonstration of instrumentation of AAS, Flame photometry, Fluorescence spectrometer, GPC, Electrochemical work station etc.

Recommended Text Books:

6. A. Findlay, Practical Physical Chemistry, 9^{th} ed., Longman, 1973.
7. D. P. Shoemaker, C.W. Garland, J.W, Nibler, Experiments in Physical Chemistry, 5^{th} ed., McGraw Hill, 1989.
8. J. B. Yadav, Advanced Practical Physical Chemistry, 36^{th} ed., KrishnaPrakashan Media (P) Ltd, 2016.
9. J. N. Gurtu, A.N. Gurtu, Advanced Physical Chemistry Experiments, 6^{th} ed., Pragati, 2014.

CORE/LAB

CHE 10807

OPEN ENDED LAB-IV

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1 : Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validating the hypothesis.

The students shall submit a project progress report

ELECTIVE

CHE 10808

BIOANALYTICAL CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Demonstrate key features and characteristics of major biomolecules.	Understand
C.O.2: Describe and explain the principles and applications of MRI and NMR for bioanalysis.	Understand
C.O.3: Outline the principles and theory of major types of electrophoresis and electrophoretic separation.	Apply
C.O.4: Explain the theory and applications of biochemical analysis like RIA, ELISA.	Analyze
C.O.5: Appreciate the variety of popular methods to separate and isolate biomolecules.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x				x		x		
C.O.3	x	x				x		x		
C.O.4	x	x				x		x		
C.O.5	x	x				x		x		

UNIT – 1 **(10 hrs)**

Biomolecules- amino acid, protein, nucleic acid –structures, physical and chemical properties, features and characteristics of major biomolecules, structure-function relationship, significance. Different methods for the estimation of protein. Transition metals in health and disease - Importance of transition metals in physiological processes, Therapeutic implications of transition metals.

UNIT – 2 **(8 hrs)**

Transmission electron Microscopy (TEM), Scanning electron Microscopy (SEM) – Instrumentation and its biological applications. Nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI) technologies: key tools for the life and health sciences. Principles of NMR and the importance of this biomolecular analytical technique. Established and emerging applications of NMR. Principles and uses of MRI. MRI as a principal diagnostic and research tool.

UNIT – 3 **(4 hrs)**

Electrophoretic techniques – Principles of electrophoretic separation. Types of electrophoresis including paper, gel. Electroporation, Pulse field gel electrophoresis- applications in life and health science.

UNIT – 4 **(4 hrs)**

Radio immune assay (RIA) - principle and applications. Enzyme linked immune sorbent assay (ELISA) principle and applications. Biosensors-applications.

UNIT – 5 **(6 hrs)**

Principle of centrifugation, concept of RCF, features and component of major types of centrifuge, preparative, differential and density gradient centrifugation, analytical ultra-centrifugation, centrifugation. Flow cytometry: principles and applications of this core method of separation.

Recommended Text Books:

1. V. A. Gault, N. H. Mcclenaghan, Understanding bio analytical chemistry - principle and applications, John Wiley and Sons, Ltd Publications, 2009.
2. A. Manz, N. Pamme, D. Iossifidis, Bio-analytical Chemistry, 2004
3. S. R. Mikkelsen, E. Corton, Bio Analytical Chemistry, John Wiley and Sons, Ltd Publications, 2004.
4. K. Wilson, J. Walker, Practical Biochemistry-Principles and techniques, 5th ed., Cambridge University press, 2000.

Semester 8

ELECTIVE

CHE 10809

ADVANCED PHOTOCHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Describe various photochemical and photophysical processes and apply established experimental methods for the investigation of these processes.	Apply
C.O.2: Explain theories of photoinduced electron transfer and reactivity of excited states and their significance in different fieldsincluding biomedical applications and photosynthesis.	Evaluate
C.O.3: Apply the knowledge of photochemistry of semiconductors and advanced materials for various applications involving photochemical energy conversions.	Apply
C.O.4: Explain theory and application of photocatalysis and explain the environmental impact of atmospheric photochemistry.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x						x		
C.O.3	x	x			x			x		
C.O.4	x	x	x		x			x		

UNIT – 1 **(8 hrs)**

Energy Transfer-Theories of Energy Transfer – Photosensitization of Organic and Inorganic Molecules – Singlet Oxygen – Methods of singlet oxygen generation and Detection – Chemistry of Singlet Oxygen – Photodynamic Therapy of Cancer.

UNIT – 2 **(8 hrs)**

Photoinduced Electron Transfer – Theory of Electron transfer – Circumventing Back Electron transfer – Photoinduced Electron transfer reactions of Organic and Inorganic Molecules – Photosynthesis.

UNIT – 3 **(4 hrs)**

Photochemistry and Photophysics of Semiconductors – Semiconductor Photocatalysis and applications. Atmospheric photochemistry

UNIT – 4 **(6 hrs)**

Photochemistry and Advanced Materials - Artificial Solar Energy Harvesting – Photochemical Splitting of Water – Dye sensitized solar cells - Grätzel Cell - Bulk heterojunction devices for solar energy harvesting - Organic light emitting devices. Photoresists – Photolithography – Photochromism – Photonic Materials and Lasers.

UNIT – 5 **(6 hrs)**

Photochemistry in Practice – Radiometry and Actinometry – Principles of Radiometry and radiometers – Actinometry – Quantum Yields – Light Sources – Optical Materials and Filters – Photochemical Reactors.

Recommended Text Books:

1. N. J. Turro, V. Ramamurthy, J. C. Scaiano, Modern Molecular Photochemistry of Organic Molecules, University Science Books, 2010.
2. C.E. Wayne, Photochemistry (Oxford Chemistry Primers), Oxford University Press; 1st ed., 1996.
3. J. R. Lakowicz, Principles of Fluorescence Spectroscopy, Plenum Press, 3rd ed., 2010.
4. A. M. Braun, M.-T. Maurette, Esther Oliveros, Photochemical Technology, John Wiley & Sons, 1991.
5. M. A. Fox, M. Chanon, Photoinduced Electron Transfer Part A, B. C and D, Elsevier Science Publishing Company, 1988.
6. J. Mattay Ed., Photoinduced Electron Transfer 1-5 (Topics in Current Chemistry), Springer, 1st ed., 1990-1993.

7. G. J. Kavarnos, Fundamentals of Photoinduced Electron Transfer, 1st ed., Wiley-VCH, 1993.
8. V. Ramamurthy, K. Schanze, Molecular and Supramolecular Photochemistry, Volume 10, Semiconductor Photochemistry and Photophysics, Marcel Dekker,New York, 2003.
9. V. Ramamurthy, Photochemistry in Organized and Confined Media, VCH Publishers, New York, 1991.

ELECTIVE

CHE 10810

THEORY OF ORBITAL INTERACTIONS IN CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Examine the physical properties associated with molecules and the pathways taken by chemical reactions.	Analyse
C.O.2: Correlate qualitatively the shape and energy of orbitals and the chemical reaction exhibited by any molecule.	Apply
C.O.3: Explore the effects of symmetry, overlap, and electronegativity in the molecular orbital in case of chemical reaction.	Evaluate
C.O. 4: Explore the structures and reactivity relationships associated with any molecule.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x			x			x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		

UNIT – 1 **(6 hrs)**

Atomic and Molecular Orbitals, Concepts of Bonding and Orbital Interaction, Orbital Interaction Energy, Molecular Orbital Coefficients, Electron Density Distribution, Perturbational Molecular Orbital Theory, Linear H_3, HF, and the Three-Orbital Problem.

UNIT – 2 **(10 hrs)**

Molecular Orbital Construction from Fragment Orbitals, Triangular H_3, Rectangular and Square Planar H_4, Tetrahedral and Linear H_4, Pentagonal H_5 and Hexagonal H_6, Molecular Orbitals of Diatomic Molecules and Electronegativity Perturbation, Geometrical Perturbation of Molecular orbitals, Molecular Orbitals of AH_2, Walsh Diagrams, Jahn–Teller Distortions.

UNIT – 3 **(6 hrs)**

Molecular Orbitals of Small Building Blocks, AH System, AH_3 Systems, pi-Bonding Effects of Ligands, AH_4 System, Molecules with Two Heavy Atoms, A_2H_6 Systems, Orbital Interactions through Space and through Bonds.

UNIT – 4 **(4 hrs)**

Polyenes and Conjugated Systems, Acyclic Polyenes, Huckel Theory, Cyclic Systems, Conjugation in Three Dimensions, Solids, Energy Bands, Hypervalent Molecules.

UNIT – 5 **(6 hrs)**

Transition Metal Complexes. Octahedral ML_6, pi-Effects in an Octahedron, Distortions from an Octahedral Geometry, Square Planar, Tetrahedral ML_4 Complexes, Five Coordination, Square Pyramidal ML_5 Fragment, ML_3 Fragment, ML_2 and ML_4 Fragments, M_2L_8 Dimers, CpM and Cp_2M, Isolobal Analogy.

Recommended Text Books:

1. T. A. Albright, J. K. Burdett, M.-H. Whangbo, Orbital Interactions in Chemistry, 2nd ed., John Wiley and Sons, Inc., Hoboken, New Jersey, 2013.
2. I. Flemming, Molecular Orbitals and Organic Chemical Reactions, Students ed., Wiley, 2009.
3. A. Rauk, Orbital Interaction Theory of Organic Chemistry, 2nd ed., Wiley-Blackwell, 2000.
4. W. L. Jorgensen, L. Salem, The Organic Chemist's Book of Orbitals, Academic Press, 1973.

CORE

CHE 10901

ANALYTICAL CHEMSITRY-II

(ADVANCED ANALYTICAL TECHNIQUES AND INSTRUMENTAL METHODS)

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Explain the theory, instrumentation and applications of various electroanalytical techniques, chromatographic, thermal and surface analysis	Apply
C.O.2: Predict appropriate chromatographic methodology for separation of a given mixture	Analyse
C.O.3: Perform separation of components in a mixture using GC-MS and HPLC	Evaluate
C.O.4 : Perform individual and simultaneous voltammetric analysis of samples	Evaluate
C.O. 5 : Analyse the surface of various samples using SEM, AFM, TEM	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X									
C.O.2	X	X								
C.O.3	X	X	X	X		X	X		X	
C.O.4	X	X	X	X		X	X		X	
C.O. 5	X	X	X	X						

UNIT – 1 **(18 hrs)**

Potentiometry: different types of indicator electrodes, limitations of glass electrode, applications in pH measurements, other types of ion selective electrodes, solid, liquid, gas sensing and specific types of electrodes, biomembrane, biological and biocatalytic electrodes as biosensors, importance of selectivity coefficients. CHEMFETS- importance of specially designed amplifier systems for ion selective electrode systems. Potentiometric titrations- types and applications.

Electrogravimetry- electrogravimetry without potential control, controlled potential electrogravimetry, applications

Coulometry- constant current and constant potential coulometry, applications- primary and secondary coulometry, advantages of coulometric titrations

Conductance measurement – conductometric titrations

Polarography – current – voltage curve, DME-components of polarographic current, supporting electrolyte, polarographic maxima. Half-wave potential, Applications of Polarography

Voltammetry - different types, Theory and applications

Stripping analysis. Amperometric titrations – Different types and Applications

Impedance spectroscopy, Voltammetric sensors – individual and simultaneous analysis-Case study

UNIT – 2 **(12 hrs)**

Gas chromatography – basic instrumental set up-inlets, carriers, columns, detectors and comparative study of TCD, FID, ECD, NPD and MS. Qualitative and quantitative studies using GC, Preparation of GC columns, packet columns and capillary columns, selection of stationary phases of GLC, Choosing theparameters- Temperature, Length of the column, Sample size, Flow rate

CHN analysis by GC, Case study

GC Capillary electrophoresis-migration rates and plate heights, instrumentation, sample introduction, detection methods, applications. Capillary gelelectrophoresis. Capillary isotachophoresis. Isoelectric focusing.

Capillary electro chromatography-packed columns. Micellar electro kinetic chromatography.

and GC-MS applications

UNIT – 3 **(12 hrs)**

HPLC – Separation process, Eddy diffusion, Mass transfer, Longitudinal diffusion, Retention parameters in HPLC-Capacity factor, Retention time, Retention volume, Peak width, Total number of theoretical plates, Height equivalent of a theoretical plate, Resolution and retention time, Solvent delivery systems, Detectors

Instrumentation and functioning of HPLC, Types of HPLC - Modes of separation in HPLC-adsorption chromatography, reversed phase chromatography, ion pair chromatography, ion exchange chromatography Solubility and retention in HPLC Method development in HPLC - Selection of mobile phase and optimization, Preparation of sample, Selection of column and solvent

HPLC method validation, HPLC Analysis -Case study Dos and Don’ts in HPLC - Troubleshooting in HPLC

UNIT – 4 **(12 hrs)**

Measurement of alpha, beta, and gamma radiations, neutron activation analysis and its applications. Principle and applications of isotope dilution methods, Radioimmunoassay (RIA), Immunoradiometric assay (IRMA), Enzyme linked immunosorbent assay (ELISA)-Principles and practical aspects

Thermal methods of Analysis TG, DTA and DSC - Instrumentation and Theory – Factors affecting TGA - effect of atmosphere on DTA. TG of copper sulphate pentahydrate and calcium oxalate monohydrate. Application of thermal methods for identification of substances.

UNIT – 5 **(10 hrs)**

Chemical Analysis of surfaces: Surface preparations-ion scattering spectrometrysecondary ion scattering microscopy (SIMS)-Auger election spectroscopy-ESCA instrumentation and application.

Principle, instrumentation and applications of SEM, TEM and AFM, Case study

Recommended Text Books:

1. J.M. Mermet, M. Otto, R. Kellner, Analytical Chemistry, Wiley-VCH, 2004.
2. D.A. Skoog, D.M. West, F.J. Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8th Edn., Saunders College Pub., 2007.
3. J.G. Dick, Analytical Chemistry, R.E. Krieger Pub., 1978.
4. J.H. Kennedy, Analytical Chemistry: Principles, Saunders College Pub., 1990.
5. G.H. Jeffery, J. Bassett, J. Mendham, R.C. Denney, Vogel's Text Book of Quantitative Chemical Analysis, 5th Edn., John Wiley& sons,1989.
6. C.L. Wilson, D.W. Wilson, Comprehensive Analytical Chemistry, Elsevier, 1982.
7. G.D. Christian, J.E. O'Reilly, Instrumental Analysis, Allyn & Bacon, 1986.
8. R.A. Day, A.L. Underwood, Quantitative Analysis, Prentice Hall, 1967.
9. H.A. Laitinen, W.E. Harris, Chemical Analysis, McGraw Hill, 1975.
10. F.W. Fifield, D. Kealey, Principles and Practice of Analytical Chemistry, Blackwell Science, 2000.
11. Contemporary Instrumental Analysis, Kenneth A. Rubinson, Judith F. Rubinson, Prentice Hall, New Jersey, 2000.
12. Wilson & Wilson's, Comprehensive Analytical Chemistry, Volume 47, Modern Instrumental Analysis, Edited by S. Ahuja, N. Jespersen, Reed Elsevier India Private Ltd., Noida, 2006.
13. Journal of Chromatography Library, Volume 3, Liquid Column Chromatography-A Survey of Modern Techniques and Applications, Edited by Z. Deyl, K. Macek, J. Janak, Elsevier Scientific Publishing Company, Amsterdam, 1975.
14. Gas Chromatography, John Willett, John Wiley & Sons, Singapore, 1991.
15. Fundamentals of Analytical Chemistry, Doughlas A. Skoog, Donald M. West, F. James Holler, Stanley R. Crouch, 9th Ed., Cengage Learning, 2014.
16. Allen J. Bard, Larry R. Faulkner, Electrochemical Methods-Fundamentals and Applications, John Wiley & Sons, New York, 1980.

CORE

CHE 10902

Inorganic Chemistry – V

(ORGANOMETALLIC AND BIOINORGANIC CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Distinguish the different types of ligands with respect to the type of interaction with the metal.	Analyse
C.O. 2: Evaluate the structure, bonding and reactions of organometallic compounds and metal clusters.	Evaluate
C.O.3: Predict the stability of organometallic compounds and metal clusters.	Apply
C.O.4: Explain the application of reactions of organometallic complexes in homogeneous catalytic processes.	Apply
C.O.5: Identify the role of metals in biological systems.	Apply

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x			x			x		
C.O.3	x	x			x			x		
C.O.4	x	x			x			x		
C.O.5	x	x						x		

UNIT – 1 **(8 hrs)**

Compounds with transition metal to carbon bonds: eighteen electron rule; classification of ligands, nomenclature, σ donor ligands – metal alkyl, aryl complexes; σ donor/π acceptor ligands, – metal alkenyls, alkynyls, carbenes, carbynes, carbonyls, isocyanide, fluxionality of ligands – structure, bonding, spectra, preparation and reactions.

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UNIT – 2 **(8 hrs)**

σ, π donor/π acceptor ligands – olefin complexes, alkyne, allyl, enyl complexes, metallocene- ferrocene, titanocene, zircanocene, arene complexes, cycloheptatriene, cyclooctatetraene, cyclobutadiene complexes, fluxionality of ligands – structure, bonding, preparation, reactions and spectroscopy

UNIT – 3 **(8 hrs)**

Metal–Metal bonds and Transition metal clusters; preparation, properties and spectroscopy. Parallels with nonmetal chemistry- isolobal analogy. Application of Wade-Mingos-Lauher rules in predicting thestructure of organometallic clusters

UNIT – 4 **(12 hrs)**

Reactions of organometallic complexes – Ligand cone angle, oxidative addition, reductive elimination, insertion, nucleophilic and electrophilic attack of coordinated ligands. Homogeneous catalysis using organometallic compounds: olefin hydrogenation, hydroformylation, Wacker process, Ziegler-Natta polymerisation, cyclo oligomerisation, olefin isomerisation, olefin metathesis, Monsanto acetic acid synthesis, Fischer-Tropsch process, hydrosilylation, coupling reactions in organic chemistry

UNIT – 5 **(12 hrs)**

Metal ions in biological systems: Heme proteins – hemoglobin, myoglobin

Non-Heme Iron Proteins: Iron storage and transfer – ferritin, transferrin; electron transfer (Iron-sulfur protein) – rubredoxin, ferredoxin; O2 transport – hemerythrin

Copper proteins and Enzymes – Hemocyanin, superoxide dismutase, ceruloplasmin, cytochrome coxidase;

Zinc and Cobalt enzymes – carbonic anhydrase, carboxypeptidase, interchangeability of zinc and cobaltenzymes; Vitamin B12 and B12

Photosynthesis and N2 fixation Metals in medicines and therapy

Recommended Text Books:

1. Ch. Elschenbroich, A. Salzer, Organometallics – A Concise Introduction, VCH Publishers, 1989.
2. B. D. Gupta, A. J. Elias, “Basic Organometallic Chemistry”, University Press, 2010.
3. P. Powell, Principles of Organometallic Chemistry, 2nd ed., ELBS, 1991.
4. J. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry: Principles of structure and Reactivity, 4th ed., Harper Collin College Publishers, 1993.
5. E.-I. Ochiai. Bioinorganic Chemistry – An Introduction, Allyn and Bacon Inc., 1977.
6. N. Kaim, B. Schwederski. Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, John Wiley, 1994.
7. Bertini, H. B. Gray, S. J. Lippard, J. S. Valentine, Bioinorganic Chemistry, Viva Books, 1998.
8. R. W. Hay, Bio Inorganic Chemistry, Ellis Horwood, 1987.
9. J. A. Cowan, Inorganic Biochemistry – An Introduction, 2nd ed., VCH, 1997.
10. N. S. Hosmane (Ed) Boron Science: New Technologies and Applications, CRC Press, 2011.
11. S. J. Lippard, J. M. Berg. Principles of Bioorganic Chemistry, Panima Publ. Corpn. 2005.
12. M. N. Hughes, The Inorganic Chemistry of Biological Processes, Wiley, 1981.

CORE

CHE 10903

ORGANIC CHEMISTRY-VI

(CHEMISTRY OF NATURAL PRODUCTS)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Device synthesis scheme for heterocyclic aromatic and nonaromatic organic compounds.	Analyse
C.O.2: Elucidate structure and device synthesis for important natural products.	Apply
C.O.3: Describe molecular structure of carbohydrates, proteins, DNA, RNA and synthesis of vitamin C and shikimic acid.	Understand

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x	x					x		
C.O.2	x	x	x					x		
C.O.3	x	x	x					x		

UNIT – 1 **(6 hrs)**

Nomenclature and general characteristics of heterocyclic compounds. Structure, properties, synthesis and reactivity of three and four-membered ring heterocycles containing one heteroatom.

UNIT – 2 **(10 hrs)**

Heteroaromatic compounds (five and six-membered rings) containing one or two heteroatoms. Fused ring compounds: Synthesis and properties of indole, quinoline, isoquinoline, coumarin, flavone, purine and pyrimidine bases present in nucleosides.

UNIT – 3 **(12 hrs)**

Terpenoids: Classification, biosynthesis. Structure elucidation and synthesis of abietic acid. Steroids: classification, biosynthesis. Structure elucidation of cholesterol, conversion of cholesterol to progesterone, androsterone and testosterone. Fatty acids: structure, biosynthesis. Prostaglandins-classification, structure, biosynthesis and synthesis.

Alkaloids: Classification, isolation, structure elucidation based on degradative reactions (quinine and atropine). Biosynthesis of quinine and papaverine.

UNIT – 4 **(10 hrs)**

Carbohydrates: Structure of ribose, glucose, fructose, maltose, sucrose, lactose, starch cellulose and cyclodextrins. Preparation of alditols, glycosides (O, C, and N), deoxysugars. Synthesis of Vitamin C from glucose. Nucleic acids: Structure and synthesis, genetic code, recombinant DNA, biosynthesis of shikimic acid.

UNIT – 5 **(10 hrs)**

Aminoacids, peptides and enzymes: Synthesis of aminoacids – Strecker and azalactone synthesis, enantioselective synthesis of aminoacids, reactions of aminoacids. Structure of proteins, introduction to enzymes and coenzymes with special reference to the function of chymotrypsin, NAD, thiamine, pyridoxal. In vitro and in vivo synthesis of peptides, solid phase synthesis.

Recommended Text Books:

1. F. A. Carey, R. J. Sundberg, Advanced Organic Chemistry (parts A and B), 5th ed., Springer, 2008.
2. I. L. Finar, Organic Chemistry Volumes 1 & 2, 6th ed., Pearson Education Asia, 2004.
3. J. Clayden, N. Green, S. Warren, P. Wothers, Organic Chemistry, 2nd ed., Oxford University Press, 2012.

4. N. R. Krishnaswamy, Chemistry of Natural Products; A Unified Approach, Universities Press, 1999.
5. R. J. Simmonds, Chemistry of Biomolecules: An Introduction, RSC, 1992.
6. R. O. C. Norman, Principles of Organic Synthesis, 2^{nd} ed., Chapman and Hall, 1978.
7. J. A. Joule, K. Mills, Heterocyclic Chemistry, 5^{th} ed., Wiley, 1998.
8. J. J. Li, E. J. Corey, Total Synthesis of Natural Products: At the Frontiers of Organic Chemistry, Springer, 2012.
9. T. Eicher, S. Hauptmann, The Chemistry of Heterocycles, 2^{nd} ed., Wiley, 2003.
10. K. C. Nicolaou, S. A. Snyder, Classics in Total Synthesis II: More Targets, Strategies, Methods, Wiley, 2003.

CORE

CHE 10904

PHYSICAL CHEMISTRY-IV

(CHEMICAL KINETICS, REACTION DYNAMICS, CATALYSIS AND SURFACE CHEMISTRY)

Credit 3 **48 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Interpret the basic reaction dynamics and obtain the rate constants for reactions in gaseous state and solutions.	Analyse
C.O. 2: Calculate thermodynamic parameters from kinetic data.	Apply
C.O. 3: Interpret the kinetics of unimolecular, termolecular and fast reactions.	Apply
C.O. 4: Identify isotope effects in reactions	Analyse
C.O. 5: Apply the principles of acid-base and enzyme catalysis to solve any given kinetic data.	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	X	X			X					
C.O.2	X	X			X					
C.O.3	X	X			X					
C.O.4	X	X			X					
C.O.5	X	X			X					

UNIT – 1 **(8 hrs)**

Complex Reactions- Parallel, Consecutive and Opposing reactions, Steady state Approximation, Kinetics of chain reactions - Photochemical reactions H_2-Cl_2 and H_2-Br_2 reaction, Organic decomposition reactions-Rice Herzfield mechanism (acetaldehyde and ethane), Branched Chain Reactions, Explosions-

Semenov Hinshelwood mechanism (H_2-O_2 reaction),

Fast Reactions- Relaxation methods- Perturbations, Flash photolysis and Pulse radiolysis

UNIT – 2 **(10 hrs)**

Molecular reaction dynamics: Reactive encounters, Theories of reaction rates- Collision Theory. Collision and reaction cross section. Activated Complex Theory- PES, Erying equation, Comparative evaluation of collision and transition state theory, Thermodynamic treatment of reaction rates. Theory of unimolecular reactions- Lindemann Mechanism, Modifications to Lindemann mechanism- Hinshelwood, RRK and RRKM model. Termolecular reactions.

Molecular beam methods, Stripping and rebound mechanism

UNIT – 3 **(10 hrs)**

Reactions in Solutions – Cage effect, Transition state theory for reactions in solutions, Effect of ionic strength, dielectric constant and Internal pressure. Primary and secondary salt effect. Solute-solvent interactions. Ion dipole and dipole-dipole reactions. Diffusion controlled reactions.

Isotope effects: Equilibrium isotope effects. Primary and Secondary kinetic isotope effects.

UNIT – 4 **(10 hrs)**

Surfaces and interfaces: Surface free energy and Surface tension, Contact angles and Wetting, Surface films. capillarity, vapour pressure of droplets- Kelvin equation. pressure difference across curved surface -Laplace equation, Surface wetting- hydrophilicity and hydrophobicity.

Physical and chemical adsorption. Adsorption isotherms- Langmuir (kinetic and statistical derivation), Freundlich and BET (derivation) isotherms, Determination of surface area using Langmuir and BET isotherms, Isosteric heat of adsorption. Thermodynamics of adsorption- Gibbs adsorption isotherm.

UNIT – 5 **(10 hrs)**

Catalysis and Inhibition, heterogeneous Catalysis – Transition state theory, General mechanism. General Mechanism of homogeneous catalysis- Arrhenius and vant Hoff intermediates, Acid base catalysis- specific and general acid catalysis, Enzyme catalysis- Michaelis-Menten Mechanism, Competitive and non competitive inhibition. Unimolecular and bimolecular Surface reactions- Kinetics of adsorption- Langmuir Hinshelwood mechanism and Rideal-Eley mechanism.

Autocatalysis- Oscillatory reactions- Lotka- Volterra, Oregonator, Brussellator.

Recommended Text Books:

1. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York.
2. K. J. Laidler, Chemical-Kinetics, McGraw Hill, New York.
3. M. R. Wright, An Introduction to Chemical Kinetics, Wiley, 2004.
4. Richard Masel, Chemical kinetics and Catalysis, Wiley Interscience.
5. P. W. Atkins, Physical Chemistry 8th Edn., Wiley, New York.
6. Christian Reichardt, Solvents and Solvent effects in Organic Chemistry, Wiley VCH 2003.
7. A. W. Adamson, The Physical Chemistry of Surfaces, 2nd Edn., Wiley. New York.
8. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York.
9. K. J. Laidler, Chemical-Kinetics, McGraw Hill, New York.
10. M. R. Wright, An Introduction to Chemical Kinetics, Wiley, 2004.
11. A. Somorjai, Chemistry of Surfaces, 3rd Edn. Wiley, New York.
12. Clark, "Theory of adsorption and catalysis", Academic Press, 1970.
13. J.M. Thomas & W.J. Thomas, "Introduction to principles of heterogeneous catalysis", Academic Press, New York, 1967.
14. R.H.P. Gasser, "An introduction to chemisorption and catalysis by metals", Oxford, 1985.
15. D.K Chakraborthy, "Adsorption and catalysis by solids", Wiley Eastern Ltd. 1990.

CORE

CHE 10905

PHYSICAL CHEMISTRY-V

ADVANCED ELECTROCHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: describe the theories effecting ionic conductance and apply the concepts to calculate conductance behaviour of a given system.	Apply
C.O.2: describe the electronic conductance behaviour in charged interfaces and analyse the catalytic behaviour of a system.	Analyse
C.O.3: learn the working principle and advancement in futuristic electrochemical devices.	Understand

	Programme Outcomes							
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6	P.O.7	P.O.8
C.O.1	x	x						x
C.O.2	x	x						x
C.O.3	x	x				x		x

UNIT – 1 **(6 hrs)**

Review of basic concepts, Ionic Conductance, Ion Solvent Interactions, Ion-Water Interactions, Coordination Number, Solvation numbers, Hydration of simple cation, anion, and transition metal ion. Ion-Ion Interaction, Debye-HuckelTheory, Ionic Atmosphere, time of Relaxation, Mechanism of Electrolytic Conductance, Linearized P-B equation, Activity and Activity Coefficient of Electrolytes, Validity of Deby-Huckel theory., Debye-Hückel limiting law,
Debye-Hückel-Bronsted Equation.

UNIT – 2 **(8 hrs)**

Ion transport, Fick's law of diffusion, Diffusion Coefficient, Ionic drift in presence of electric field, drift velocity, transport number, Debye-Huckel- Onsager Equation, Relaxation effect, time of relaxation, Determination of degree of dissociation, Debye-Falkenhagen Effect, Wien Effect.

Ionic liquids, Limiting case of zero solvent-pure electrolyte, features of ionic liquid, diffusion in IL, ionic conductance IL, liquid oxide electrolytes.

UNIT – 3 **(8 hrs)**

Electrodics, Charged Interfaces, Electrode Potential, Factors Influencing electrode potential, Band Bending, electrolytic polarization, dissolution and decomposition potential, concentration polarization. Concentration cells.

Structure of electrified interfaces, liquid junction potential, the electrode double layer, electrode-electrolyte interface, different models of double layer, theory of multilayer capacity, electrocapillary, Lippmann equation, membrane potential

UNIT – 4 **(6 hrs)**

Electrode kinetics, Ion adsorption, Electron Transfer Under an Interfacial Electric Field, Overvoltage, theories of overvoltage, Tafel equation, Butler-Volmer equation. Electrocatalyst- Homogeneous, heterogeneous, Randles-Sevcik Equations, Pourbiax diagrams, PCET.

UNIT – 5 **(4 hrs)**

Semiconductor electrode interface. Band bending, photoelectrochemistry, fuel cells, battery-metal –ion, metal-air battery, Corrosion, Bioelectrochemistry – nervous system, enzyme as electrodes.

Recommended Text Books:

1. J. Bockris, A. K. N. Reddy, Modern Electrochemistry-1 Ionics, 2nd ed., Springer Science & Business Media, 2018.
2. J. Bockris, A. K. N. Reddy, M. E. Gamboa-Aldeco, Modern Electrochemistry-2A: Fundamentals of Electrodics, 2nd ed., Springer Science & Business Media, 2018.
3. J. Bockris, A. K. N. Reddy, Modern Electrochemistry 2B: Electrodics in Chemistry, Engineering, Biology and Environmental Science, 2nd ed., Springer Science & Business Media, 2018.
4. R. Crow, Principles and Applications of Electrochemistry, 4th ed., 1994.
5. S. Glasstone, An Introduction to Electrochemistry, Paperback ed., 2007.

CORE/LAB

CHE 10906

OPEN ENDED LAB-V

Credit 2 **96 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Design experiments and validate the hypothesis of an independent research problem.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x	x	x	x	

UNIT – 1

The students shall perform literature review/ experiments/analysis for validating the hypothesis.

The students shall submit a project report and appear for viva-voce.

ELECTIVE

CHE 10907

OLEOCHEMICALS, NUTRACEUTICALS AND SURFACTANT TECHNOLOGY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Able to classify and demonstrate the use of oils.	Apply
C.O.2: Analyse and characterize oleocemicals, nutraceuticals and surfactants.	Analyse
C.O.3: Evaluate the techniques of preparation and purification of oils.	Evaluate
C.O.4: Prepare formulation of soaps, detergents and cosmetics.	Create

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x		
C.O.2	x	x		x				x		
C.O.3	x	x					x	x		
C.O.4	x	x	x		x			x		

UNIT – 1 **(8 hrs)**

General Introduction, Sources of edible oils and fats, Processing and refining, Stability and Antioxidants, Analysis testing and QC. Introduction to essential oils and comparison with other oils. Raw materials, processing, purification and isolation of essential oil, Conventional and advance methods of production of essential oils, Synthetic Aroma chemicals and aromatherapy, Physicochemical and sensory Analysis and quality control in industry , Detail study of selected essential oils related to production, isolation, applications etc. (3 examples), Applications in soaps, detergents, cosmetics industry, flavors etc. Oleochemical

Industry and Market Information.

UNIT – 2 **(8 hrs)**

Introduction to nutraceuticals: definitions, synonymous terms, claims for a compound as nutraceutical, regulatory issues. Study of Properties, structure and functions of various Nutraceuticals (3 examples) formulation of functional food, stability, analysis. Food as remedies, Anti-nutritional Factors present in Foods, Nutraceutical Industry and Market Information.

UNIT – 3 **(4 hrs)**

Soaps and Detergent – Introduction, Chemistry, Classification, Manufacture and Environmental aspects, Analysis of Soaps surfactants and detergents: determination of surface tension, interfacial tension, and CMC, Testing of TFM of soap, % active matter of detergents.

UNIT – 4 **(6 hrs)**

Recent developments- Spray Dried Powdered Detergents, Concept of HLB and other related terms, detersive system, micro emulsion, multiple emulsion system, nanoemulsion system. Disinfectants, Surfactant Industry and Market Information.

UNIT – 5 **(6 hrs)**

Hydraulic expelling, Solvent extraction and separation of oils and fats, Aqueous extraction, Liquid liquid extraction for deacidification, Miscella refining and double solvent refining, High pressure fat splitting, fatty acid distillation, Saponification of Oils, Soap formulation and Plodder Processing, Synthesis various anionic, cationic, nonionic and amphoterric surfactants, Formulation and Processing of Detergent Powder by combined absorption and neutralisation mode**,** Purification of wax, Formulation and Processing of different Skin and Hair Care Products. Production Management, Marketing.

Recommended Text Books:

1. B.K. Sharma, Industrial Chemistry, GOEL Publishing House, 2000.
2. Mohammad Farhat Ali, Bassam Ali, James Speight, Handbook of Industrial Chemistry Organic Chemicals, McGraw-Hill 2005.
3. O. P. Narula, Treatise on fats, fatty acids and oleochemicals by, Industrial Consultants (India), Vo. I & II, 1994.
4. V. V. S. Mani and A. D. Shitole, Fats, Oleochemicals and surfactants challenges in 21st Century by Oxford and IBH Publishing Co. Pvt. Ltd., 1997.
5. Robert E. C. Wildman, Handbook of Nutraceuticals and Functional Foods, CRC Press 2016.

ELECTIVE

CHE 10908

MATERIALS CHEMISTRY

Credit 2 **32 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O. 1: Evaluate a material in terms of its properties and device plausiblesynthetic strategies.	Analyse
C.O. 2: Suggest the applicability of a given material for a specific application.	Analyse

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x						x	x	
C.O.2	x	x		x				x	x	

UNIT – 1 **(8 hrs)**

Chemistry of Materials. Historical perspectives – strategies for the design of new materials- a critical thinking approach. Ionic and covalent solids. Molecular and metallic solids. Amorphous and crystalline materials. Crystalline state. Structural organization of crystalline solids-theories of bonding. Crystal structures. Imperfections in crystal structures. Amorphous materials – glasses and ceramic solids. Structural organization of amorphous solids. Traditional ceramics. Synthetic high performance ceramics. Crystal structure of ceramics.

UNIT – 2 **(8 hrs)**

Metals and alloys. Structural and bonding theories of metals. Alloys -ferrous alloys – phase behavior of ferrous alloys. Behaviour of binary alloys. Intermediate compounds and intermediate phases. Nonferrous metals and alloys.

Shape memory alloys. PZT materials. Optical, electrical and magnetic properties of metallic materials.

UNIT – 3 **(4 hrs)**

Semiconductor materials- properties and types of semiconductors. Structure and Bonding of semiconductor materials. Silicon based semiconductors. II-VI (wide band gap) and IIIV (narrow band gap) compound semiconductors. Electrical, optical and magnetic properties of semiconductor materials. Preparation and properties of ZnO, ZnS, CdS, CdTe, Ga-As, In-S, Cu-In-S. Application in photovoltaic devices

UNIT – 4 **(6 hrs)**

Polymer Materials- classification and nomenclature of polymers. Methods of Polymerization. Dendritic and cascade polymers. Polymers via Click Chemistry. Properties of polymers. Plastics and elastomers. Viscoelastic behavior. Rubber like elasticity. Conducting polymers. Crystalline and amorphous polymers. Glass transition temperature and crystalline melting.

Polymer composites- polymer matrix composites.

UNIT – 5 **(6 hrs)**

Nanomaterials. Materials in the nanodomain. Zero, one and two dimensional materials. Particle size dependent change in properties of materials. Metals in the nanodomain. Gold and silver nanoparticles. Preparation and properties. Core shell structures. Semiconductor nanoparticles. Quantum dots. ZnO, ZnS, CdS and CdSe quantum dots. Electrical and optical properties. Nano domains of Carbon- fullerenes, carbon nanostructures, graphene. Energy and environmental applications.

Recommended Text Books:

10. Fahlman, B. D. Materials Chemistry, 2nd Ed., Springer, Heidelberg,2011.
11. Zallen, R. Physics of Amorphous Solids, Wiley, New York,1983.
12. Borg, R. J. and Dienes, G. J. The Physical Chemistry of Solids, Academic Press, Boston,1993.

13. Kingery, D.; Bowen, H. K.; Uhlmann, D. R. Introduction to Ceramics, 2nd Ed., Wiley, New York,1992.
14. Cowie, J. M. J. Polymers. Physics and Chemistry of Modern Materials, 3rd Ed., CRC Press, Boca Raton, 2007.
15. Kasap, S. O. Principles of Electronic Materials and Devises, Mc GrawHill,2006.

MOOC ELECTIVE

CHE 10909

CHEMICAL CRYSTALLOGRAPHY

Credit 4 **64 hours**

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Apply the concepts and applications of widely used experimental technique of X-ray crystallography	Analyse
C.O.2: Describe the wider significance of symmetry operation in understanding the crystal structure	Apply
C.O.3: Understand the experimental techniques for crystal preparation and selection	Understand
C.O.4: Understand the theoretical calculations involved in extracting structural information from diffraction patterns	Understand
C.O.5: Perform structure determination and refinement of crystal structures using x-ray diffraction data and software packages.	Evaluate

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x				x		x		
C.O.2	x	x				x		x		
C.O.3	x	x					x	x		
C.O.4	x	x						x		
C.O.5	x	x				x	x	x		

UNIT – 1 **(12 hrs)**

Introduction, 1D symmetry, Concept of 2D symmetry and lattices, notations of symmetry elements, space groups in 2D, 3D lattices, 32 point groups and their notations, crystal systems and Bravais lattices. Stereographic projections, Laue symmetry; glide planes, screw axes and their notations, space groups, equivalent points, space group symmetry diagrams etc. Miller Indices, crystallographic planes and directions, close pack structures, linear density, planar density, Miller-Bravais indices for hexagonal systems, various ceramic structures (NaCl, ZnS, CaF2, CsCl etc.), octahedral and tetrahedral sites.

UNIT – 2 **(12 hrs)**

What are X-rays, generation and classification of X-ray, X-ray sources, diffraction of X-rays, Bragg's law. The reciprocal lattice, reciprocal relationship, Bragg's law in reciprocal space, Ewald's sphere and sphere of reflection , Methods of crystal growth, identification of phases and morphologies, in-situ cryo crystallization, crystal growth under external stimuli etc.

UNIT – 3 **(12 hrs)**

Data collection strategies, Laue Method, Oscillation, rotation and precession methods. L-P corrections, structure factor, scaling, interpretation of intensity data, temperature factor, symmetry from intensity statistics, Structure factor and Fourier synthesis, Friedel's law; exponential, vector and general forms of structure factor, determination of systematic absences for various symmetry or lattice centering, FFT, Anomalous scattering and absolute configuration.

UNIT – 4 **(12 hrs)**

Phase problem, Direct Methods, structure invariants and semi invariants, probability methods, Phase determination in practice, Patterson Methods, Patterson Symmetry, completion of structure solution, ΔF synthesis**,** Refinement by Fourier synthesis, refinement by ΔF synthesis, Refinement by least squares method, weighting functions, Goodness-of-Fit (GOF) parameter, treatment of non-hydrogen atoms, and treatment of hydrogen atoms, treatment of disordered structures.

UNIT – 5 **(16 hrs)**

Crystal selection, indexing of crystals, data collection, data reduction, space group determination, structure solution and refinement using SHELXS97 and SHELXL97, introduction to crystallographic packages (APEX II suite, OLEX2, WinGx, PLATON) and IUCr validation of the data, Methodology, geometrical basis of powder X-ray diffraction, applications of PXRD: determination of accurate lattice parameters, identification of new/unknown phases, applications in pharmaceutical industry. Applications of powder X-ray diffraction: Structure determination from PXRD and Reitveld method for structure refinement, indexing of PXRD, handling of PXRD using DASH.

Recommended Text Books:

1. X-ray structure determination: A Practical Guide (2nd Ed.) by George H. Stout and Lyle H Jensen, Wiley-Interscience, 1989.
2. Fundamentals of Crystallography (2nd Ed.) by C. Giacovazzo, Oxford University Press, 2002
3. X-ray analysis and The Structure of Organic Molecules (2nd Ed.) Wiley-VCH, 1996
4. Chemical Applications of Group Theory (3rd Ed.) by F. A. Cotton, Wiley-India Edition, 2009.
5. The Basics of Crystallography and Diffraction by Christopher Hammond. Oxford University Press, 2015
6. Crystal Structure analysis A Primer by Jenny Pickworth Glusker and Kenneth N. Trueblood, Oxford University Press, 2010
7. Crystal Structure Analysis Principles and Practices by A. J. Blake, W. Clegg, J. M. Cole, J. S. O. Evans, P. Main, S. Persons and D. J. Watkin. Oxford University Press, 2009
8. Crystal Structure Refinement A Crystallographer's Guide of SHELXL by P. Muller, R. Herbst-Irmer, A. L. Spek, T. R. Schneider and M. R. Sawaya, Oxford University Press, 2006
9. Crystal Structure Determination by Werner Massa. Springer, 2013.

SWAYAM

Prof. Angshuman Roy Choudhury

IISER,

Semester 9

CORE/LAB

CHE 11001

PROJECT DISSERTATION

Credit 16

Course Outcome After the completion of the course the student will be able to	**Cognitive level**
C.O.1: Identify and hypothesise an advanced level research problem.	Create
C.O.2: Design experiments and validate the hypothesis of an advanced level research problem.	Create

	Programme Outcomes									
Course Outcomes	P.O. 1	P.O. 2	P.O. 3	P.O. 4	P.O. 5	P.O. 6	P.O. 7	P.O. 8	P.O. 9	P.O. 10
C.O.1	x	x	x	x	x	x		x	x	
C.O.2	x	x	x	x	x	x	x	x	x	

UNIT – 1

The students shall carry out research project in reputed research laboratory for the entire semester.

The students shall submit a project report on the research work carried out.

The students will have to present the results of the research project in a seminar and appear for a comprehensive viva-voce.

Guide lines for setting up Question Papers in Theory Courses

1. The entire syllabus must be covered in the question paper.
2. Each question must be mapped to a specific C.O.
3. All the C.O.s must be reflected in the question paper.
4. The question paper may consist of questions at different cognitive levels such that, 20% of "remember" level, 40% of "understand" level and 40% of "apply and higher" level.

END

Appendix 3

Syllabus
for

Five Year Integrated MSc
(Biological Sciences)

Centre for Integrated Studies
Cochin University of Science and Technology

(with effect from 2021-2022)

STRUCTURE AND SCHEME OF THE COURSE

SEMESTER – I

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
ENG 10101	English – I	C	50	50	100	2
MAL 10101/ HIN 10101 FLG 10101	Malayalam – I /Hindi – I German -I	C	50	50	100	2
CHE 10101	Atomic Structure and Chemical Bonding	C	50	50	100	3
PHY 10101	Mechanics	C	50	50	100	3
MAM 10101	Calculus I	C	50	50	100	4
BIO 10101	General Biology	C	50	50	100	3
CHE 10102	Inorganic Quantitative Analysis	C	100	-	100	2
PHY 10102	Physics Lab – Mechanics	C	100	-	100	2
BIO 10102	General Biology Lab	C	100	-	100	2
	Total		**600**	**300**	**900**	**23**

SEMESTER – II

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
ENG 10201	English – II	C	50	50	100	2
MAL 10201/ HIN 10201 FLG 10201	Malayalam – II/ Hindi – II German - II	C	50	50	100	2
CHE 10201	Periodicity, Nuclear Chemistry, Acid Base Chemistry and Metallurgy	C	50	50	100	3
PHY 10201	Waves and Optics	C	50	50	100	3
MAM 10201	Linear Algebra, Group Theory	C	50	50	100	4
BIO 10201	Biochemistry	C	50	50	100	3
CHE 10202	Inorganic Qualitative Analysis I	C	100	-	100	2
PHY 10202	Physics Lab – Waves and Optics	C	100	-	100	2
BIO 10202	Biochemistry Lab	C	100	-	100	2
	Total		**600**	**300**	**900**	**23**

SEMESTER – III

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
CHE 10301	Introductory Organic Chemistry	C	50	50	100	3
PHY 10301	Electricity and Magnetism I	C	50	50	100	3
MAM 10301	Calculus - II	C	50	50	100	4
MAM 10302	Mathematical Methods I	C	50	50	100	4
BIO 10302	Cell biology	C	50	50	100	3
EVS 10301	Environmental Science	C	50	50	100	2
CHE 10302	Organic Qualitative Analysis	C	100	-	100	2
PHY 10302	Physics Lab – Electricity and Magnetism	C	100	-	100	2
BIO 10302	Cell biology Lab	C	100	-	100	2
	Total		**600**	**300**	**900**	**25**

SEMESTER – IV

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
CHE 10401	Introductory Physical Chemistry	C	50	50	100	3
PHY 10401	Quantum Physics and Relativity	C	50	50	100	3
MAM 10401	Mathematical Methods II	C	50	50	100	4
STA 10401	Statistics –Probability and Statistics	C	50	50	100	4
BIO 10401	Genetics and Molecular Biology	C	50	50	100	3
COM 10401	Basic Computer Science	C	50	50	100	2
CHE 10402	Chemistry Lab – Physical Chemistry	C	100	-	100	2
PHY 10402	Physics Lab – Modern Physics	C	100	-	100	2
BIO 10402	Genetics and Molecular Biology Lab	C	100	-	100	2
	Total		**600**	**300**	**900**	**25**

SEMESTER – V

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
BIO10501	Plant Diversity I (Algae/Fungi/Bryophytes/Pteridophytes/Paleo botany)	C	50	50	100	3
BIO10502	Non-chordates	C	50	50	100	3
BIO10503	Plant Diversity II (Gymnosperms & Angiosperms)	C	50	50	100	3
BIO10504	Chordates	C	50	50	100	3
BIO 10505	Plant Lab 1	C	100	-	100	2
BIO 10506	Animal Lab 1	C	100	-	100	2
BIO 10507	Open Ended Lab – I	C	100	-	100	2
BIO 10508	Bioinformatics & Biostatistics	C	50	50	100	2
BIO10509	Animal Forms and Functions	C	50	50	100	2
	Total		**600**	**300**	**900**	**22**

SEMESTER – VI

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
BIO 10601	Microbiology	C	50	50	100	3
BIO 10602	Angiosperm (Anatomy/Physiology/Embryology)	C	50	50	100	3
BIO 10603	Evolution and Developmental Biology	C	50	50	100	3
BIO 10604	Parasitology and Immunology	C	50	50	100	3
BIO 10605	Plant Lab 2	C	100	-	100	2
BIO 10606	Animal Lab 2	C	100	-	100	2
BIO 10607	Open Ended Lab – II	C	100	-	100	2
BIO 10608	Food, Nutrition and Health	C	50	50	100	2
BIO 10609	Plant Tissue culture	C	50	50	100	2
	Total		**600**	**300**	**900**	**22**

SEMESTER – VII

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
BIO 10701	Cellular metabolism	C	50	50	100	3
BIO 10702	Cell Biology	C	50	50	100	3
BIO 10703	Enzymology	C	50	50	100	3
BIO 10704	Molecular Biology	C	50	50	100	3
BIO 10705	Biochemistry Lab	C	100	-	100	2
BIO 10706	Cell and Molecular Biology Lab	C	100	-	100	2
BIO 10707	Open Ended Lab I	…	…..	…..	…..	…..
BIO 10708	Genetics	E	50	50	100	2
BIO 10709	Breeding and Culture techniques	E	50	50	100	2
	Total		**500**	**300**	**800**	**20**

SEMESTER – VIII

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
BIO 10801	Advanced Microbiology	C	50	50	100	3
BIO 10802	Plant physiology and biochemistry	C	50	50	100	3
BIO 10803	Animal Physiology and Endocrinology	C	50	50	100	3
BIO 10804	Ethology and Chronobiology	C	50	50	100	3
BIO 10805	Microbiology Lab	C	100	-	100	2
BIO 10806	Plant and Animal Physiology Lab	C	100	-	100	2
BIO 10807	Open Ended Lab II	….	…..	….	….	…
BIO 10808	Research Methodology/ Bioethics/Biosafety/IPR	E	50	50	100	2
BIO 10809	Biophysics and Bioinstrumentation	E	50	50	100	2
	Total		**500**	**300**	**800**	**20**

SEMESTER – IX

Course Code	Name	C/E	Marks Distribution			Credit
			Continuous evaluation	End semester	Total	
BIO 10901	Immunology	C	50	50	100	3
BIO 10902	Genetic Engineering	C	50	50	100	3
BIO 10903	Computational Biology	C	50	50	100	3
BIO 10904	Environmental Biology	C	50	50	100	3
BIO 10905	Immunology Lab	C	100	-	100	2
BIO 10906	Genetic engineering and Computational Biology Lab	C	100	-	100	2
BIO 10907	Open Ended Lab III	C	100	100	100	2
BIO 10908	Genomics and Proteomics	E	50	50	100	2
BIO 10909	Molecular Taxonomy	E	50	50	100	2
	Total		**600**	**400**	**900**	**22**

SEMESTER-X

Course Code	Name	C/E	Marks Distribution			
			Continuous evaluation	End semester	Total	Credit
BIO 11001	Innovation and Entrepreneurship for Biologists	E	-	50	50	2
BIO 11002	Dissertation	C		200	200	16
	Total		**-**	**250**	**250**	**18**

PROGRAM OBJECTIVES

The Integrated M. Sc. Biology program describes accomplishments that graduates are expected to attain within three to five years after graduation

- The program will ensure an up-to-date level of understanding of the concept of basic and applied Biology.
- The program aims to articulate the importance of biology in terms of environment, medicine, agriculture, and food and use them for the development of the nation to compete at a global level.
- The program will inculcate the students with professional and research ethics at their working place.
- The program would enable the students to address the major concerns of our society in a multidisciplinary way (conserving biodiversity, public health, safety, cultural and societal development).

PROGRAM OUTCOMES (POS)

After the successful completion of the Biology program, the students are expected to

PO1. Describe fundamental principles that underlie the field of Biology (Animal Science, Plant Science, Microbiology, Biochemistry, Molecular and Cell Biology, Genetics and Genetic Engineering, Immunology, Biotechnology, Computational Biology and Research Methodology)- (Understand level).

PO2. Show proficiency in performing various basic and advanced laboratory techniques employed in Biology in academia and industries (Apply).

PO3. Design and conduct biological experiments, analyse and interpret experimental data and perform troubleshooting if necessary (Create).

PO4. Identify a research problem using a literature survey, formulate a hypothesis, develop a research plan, execute the research plan, write the project report and communicate effectively through written, oral and visual methods (Remember).

PO5. Analyze and interpret large-scale biological datasets such as phylogenetic analysis, protein structure prediction, elucidating and quantifying various biomolecules, estimate various metabolites, estimating enzyme kinetics, mutation profiling, nucleotide and protein sequence analysis and NGS analysis (Analyze).

PO6. Assess various plant /animal/microbial resources, biological techniques to develop entrepreneurship in the biological industry (Evaluate).

SEMESTER I

BIO 10101- GENERAL BIOLOGY (3C= 48 hrs)

Course description: The course covers the studies of living creatures, from the tiny and simple through to the complexities of plants and animals, ending with a basic understanding of ecology and the study of population dynamism. Different scopes of biology will also be conveyed to the students.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the biological processes common to life	Understand
C.O. 2: Compare fundamental differences in the forms and how they may differ	Analyze
C.O. 3: Comprehend and explain how present-day organisms may have arisen	Understand
C.O. 4: Interpret how different life forms, including humans, interact with each other and with the physical, chemical and biological world around them.	Analyze
C.O. 5: Use the knowledge gained through scopes of biology for higher studies and furthering careering in biology.	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4					x	
C.O.5						x

MODULE I (10 hrs)

Introduction: History of Biology, cosmic evolution & origin of life, the Chemical basis of life; diversity of life forms; Characteristic features of living organisms:-plants, animals, microorganisms, and viruses; Hierarchical levels of organization in living organisms (molecules, organelles, cells, tissues, organs, organisms, populations, communities, ecosystems); Difference between prokaryotes and eukaryotes; Modes of nutrition (Autotrophs, heterotrophs), Photosynthesis, Ingestion and absorption; concepts of basic metabolism; concepts of growth, reproduction, regulation, death, cellular basis of inheritance and their pattern.

MODULE II **(10 hrs)**

Taxonomy and systematics: Taxonomy: Definition, history, new trends and importance; Taxonomical hierarchy - taxon, category and rank, Linnaean hierarchy, Two kingdom classification, Three kingdom concept, Five kingdom classification, concept and Three domain concepts; Systematics:- Nomenclature, International Code of Algae, Fungi and Angiosperms and Zoological Nomenclature; Taxonomic aids, Techniques, tools and applications of molecular taxonomy in biology; Major classification schemes of plants, animals and microorganisms.

MODULE III **(10 hrs)**

Principles of Developmental Biology & Evolution: Basic concepts in developmental biology with reference to plants and animals, and their biological significance in genetic inheritance and organic evolution. Introduction to evolution: History, Types, Theories (Theory of Lamarck, Weismann and De Vries, Darwinism, Neo- Darwinism with suitable examples), evidence of Evolution, geological time scales, Organic evolution and Cambrian Explosion, Evolution of man.

MODULE IV **(10 hrs)**

Ecology and Conservation: Concepts and elements of Biotic and Abiotic environment; Interaction between biotic and abiotic environment and the impact; adaptation to the environment: water, air, soil; Life in extreme environments; climate-solar radiation and climate, temperature, radiation, nutrients; population ecology, symbiosis, mutualism, competition, predation, parasitism; host-pathogen/parasite interactions. Ecosystem- concept and components, Community-structure and dynamics; Biome- grassland, tundra, forest, deserts, salt & freshwater ecosystem; Biodiversity and Conservation; Impact of climate change on biodiversity.

MODULE V **(8 hrs)**

Scope of Biology: Importance of living organisms and their study with relevance to the existence of life on planet earth. Branches, applications and scope of biology. Integration of Biology with various fields for human welfare. Novel concepts and recent revolutionary discoveries in Biology. Contributions of living organisms in human health and sustenance. Biological systems or processes inspired technological inventions or innovations and harnessing these for sustainable development.

BIO 10102- GENERAL BIOLOGY LAB **(2C= 96 hrs)**

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the principle of various microscopic techniques	Understand

C.O. 2: Show the skills to independently operate microscopes for analysing and recording image data	Apply
C.O. 3: Differentiate various unicellular and multicellular life forms and identify them based on their morphology by microscopy	Analyze
C.O. 4: Identify various types of evolution with the help of pictures	Remember
C.O. 5: Evaluate the stages of development of volvox from unicellular to multicellular forms	Evaluate

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2		x				
C.O.3					x	
C.O.4				x		
C.O.5						x

1. Familiarizing microscopes and their application.
2. Microscopic examination and identification of unicellular and multicellular life forms: Monerans: Euglena, Paramecium, Amoebae, Chlamydomonas, Chlorella, Diatoms.
3. Microscopic observation of bacteria and fungi
4. Slides and videos on organic Evolution (picture demonstration)
5. Volvox as a model of evolution- (Cellular level- single cell to the multicellular organization)

REFERENCES

1. Reece, J. B., & Campbell, N. A. (2011). Campbell Biology. Boston, Benjamin Cummings / Pearson.
2. Manuel C Molles, Ecology: Concepts and Applications McGraw Hill 7th Edition 2014
3. Douglas J Futuyma, Evolution Oxford University Press 3rd Edition 2013
4. Barton et al., Evolution Cold Spring Harbor Laboratory Press 1st Edition 2007
5. Stephen C. Stearns and Rolf F. Hoekstra, Evolution: An Introduction Oxford University Press 1st Edition 2000
6. Nicholas J. Gotelli, A primer of Ecology Oxford University Press, 4th Edition 20086. Begon et al., Ecology: From Individuals to Ecosystem Wiley-Blackwell, 4th Edition 2005
7. Instant notes on ecology by A. Mackenzie, A.S. Ball, S.R. Virdee, 2nd edition- 2020

SEMESTER II

BIO 10201- BIOCHEMISTRY (3C= 48 hrs)

Course description: The program is designed to enable a student to acquire sound knowledge of biochemistry and its practical applicability. The course will encourage the students to join the industry or to prepare them for higher studies including research. The syllabus is based on a basic and applied approach to ensure that students develop problem-solving skills, laboratory skills, chemistry communication skills, team skills as well as ethics.

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the significance of biomolecules	Understand
C.O. 2: Differentiate the biomolecules (proteins, lipids, nucleic acids, and carbohydrates) based on their structural basis	Analyze
C.O. 3: Calculate the quantify various biomolecules.	Analyze
C.O. 4: Employ chromatographic techniques to separate various biomolecules.	Apply
C.O. 5: Apply proper procedures and regulations in handling and disposal of chemicals.	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4		x				
C.O.5		x				

M0DULE I (10 hrs)

A brief history of biochemistry, Basic chemistry- Elements, Functional groups, pH, Mole concept, Bonding and chirality, Non-covalent interactions, Water, interactions in aqueous systems, Molarity, normality, Ionization state of biomolecules, Laws of thermodynamics, Gibbs free energy, and maintenance of equilibrium.

M0DULE II (10 hrs)

Carbohydrates: Structure, chemical & biological properties and functions. Monosaccharides-Ribose, Glucose and fructose. Oligosaccharides -Sucrose, maltose, lactose, Polysaccharides-Glycogen, cellulose and starch. Glycoproteins, proteoglycans and glycolipids. Heteropolysaccharides, Carbohydrates as informational molecules- the sugar code, Carbohydrate metabolism: glycolysis and gluconeogenesis and TCA cycle

M0DULE III **(10 hrs)**

Nucleic Acids: Nucleotides, Nucleic Acid composition, a historical perspective leading up to the proposition of DNA double-helical structure; the difference in RNA and DNA structure and their importance in the evolution of DNA as the genetic material.Lipids & Fats: Storage lipids, Structural lipids in membranes, Lipoproteins. Lipids as signals, cofactors and pigment, Biological functions of lipids. Vitamins and Minerals: General accounts and biological functions, Lipid metabolism overview.

M0DULE IV **(10 hrs)**

Proteins, – the structure and functional group properties; pH and properties of amino acids, Peptides and covalent structure of proteins; peptide bond, polypeptide, protein structure-secondary, tertiary and quaternary, protein structure & function, Enzymes as Biological Catalysts: General principles of enzyme catalysis, Activation energy and stereospecificity, classification of enzymes; Types of enzymes and their specific functions. Enzyme characterization and Michaelis-Menten kinetics, Regulation and Inhibition of enzyme.

M0DULE V **(8 hrs)**

Methods in Biophysical and Biochemical Analysis; Buffers, pH meter, Calorimetry, Spectrophotometry, Centrifugation techniques, Mass spectrometry, Chromatographic techniques, Electrophoretic Techniques.

BIO 10202- BIOCHEMISTRY LAB (2C=96 hrs)

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the concept of Molarity, Normality, pH etc	Understand
C.O. 2: Apply standard procedures to prepare different Molar solutions and buffers of different pH.	Apply/Create
C.O. 3: Calculate the quantity of biomolecules in solutions by spectrometry	Analyze
C.O. 4: Separate biomolecules based on chromatographic techniques	Apply
C.O. 5:Differentiate various biomolecules in solutions based on colorimetric techniques	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2		x	x			

C.O.3					x	
C.O.4		x				
C.O.5					x	

1. Preparation of Normal and Molar solutions
2. Preparation of Buffers (Acidic, Neutral and Alkaline Buffers)
3. Verification of Beer Lambert's law
4. Estimation of biomolecules (glucose, protein, lipids and nucleic acid).
5. Separation of biomolecules using paper and TLC
6. Electrophoretic Techniques

REFERENCES:

1. Rodney F Boyer, Concepts in Biochemistry. John Wiley & Sons; 3rd Ed (2 December 2005).
2. Thomas Millar, Biochemistry Explained: A Practical Guide to Learning Biochemistry CRC Press; 1 edition (30 May 2002)
3. Lubert Stryer et al., Biochemistry.W. H. Freeman; 6th Edition (14 July 2006)
4. David L Nelson, and Michael M Cox et al., Lehninger principles of biochemistry WH Freeman; 7th ed.2017 edition (1 January 2017)
5. Lehninger. Principles of Biochemistry, Macmillan, U.K.
6. Geoffrey Zubay. Biochemistry. Macmillan Publishing company, New York
7. Sadasivam and Manickam. Biochemical Methods. New Age International Publishers. NewDelhi.
8. David T. Plummer, An Introduction to Practical Biochemistry. Tata McGraw Hill.
9. Nelson, D. L., Lehninger, A. L., & Cox, M. M. (2008). Lehninger principles of biochemistry. Macmillan
10. Tymoczko, J. L., Berg, J. M., &Stryer, L. (2011). Biochemistry: a short course.Macmillan.
11. Cornish-Bowden, A. (2014). Principles of enzyme kinetics. Elsevier.
12. Haynie, D. T. (2001). Biological thermodynamics. Cambridge University Press.
13. Voet, D., & Voet, J. G. (2016). Fundamentals of Biochemistry. 5th Edition. Wiley & Sons.

SEMESTER III

BIO 10301- CELL BIOLOGY **(3C= 48 hrs)**

Course description: The objective of the course is to help the students to learn and develop an understanding of a cell as a basic unit of life. This course is designed to enable them to understand the functions of cellular organelles and how a cell carries out and regulates cellular functions. The course will also provide an overview of classical and modern cell biology-based techniques.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	Cognitive Level
C.O. 1: Explain fundamental principles of cell biology.	Understand
C.O. 2: Identify and differentiate the cellular organelles using microscopy.	Analyze
C.O. 3: Identify and differentiate plant, animal and microbial cells based on morphological features and size.	Analyze
C.O. 4: Evaluate how cells grow, divide, survive, die using staining techniques.	Evaluate
C.O. 5: Describe the process of cell signaling and its role in cellular functions	Understand
C.O. 6: State how defects in the functioning of cell organelles and regulation of cellular processes can develop into diseases.	Remember
C.O. 7: List the advances made in the field of cell biology and their applications.	Remember

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4						x
C.O.5	x					
C.O.6				x		
C.O.7				x		

MODULE I **(8 hrs)**

History, development and scope of cell biology; discovery of cells; cell theory and its modern version. Cell and its components: basic types of cells- prokaryotic and eukaryotic, nature and comparison. Ultra-structural organization and functions: Plasma membrane- ultrastructure-fluid mosaic model, functions of the plasma membrane.

MODULE II **(10 hrs)**

Cellular Organelles and their functions: Mitochondria, Endoplasmic reticulum, Golgi bodies, Lysosomes, Microbodies, Ribosomes, Proteasomes, Centrioles, Cytoskeleton, Nucleus-nuclear envelope and Nucleolus, chromosomes, Nucleoproteins, Nucleosome model of DNA organization, structural and numerical variations of chromosomes, Polytene, Lamp brush and B chromosomes.

MODULE III **(10 hrs)**

Histology-Animal histology: Tissues: Epithelial tissue; types, characteristics and functions, Blood, Bone, Cartilage and Adipose tissues, Muscle tissue; Cellular and molecular mechanism of muscle contraction, Nervous tissue. Plant histology- Plant tissues; meristematic & permanent (simple complex tissues), tissue systems.

MODULE IV **(10 hrs)**

Overview of cell signaling, communication between cells, plasma membrane and nuclear receptors; hormones; ion channels; secondary messengers; Cell Division: cell cycle- Gl, S, G2, and M phases, amitosis. Mitosis & Meiosis; Cell cycle and Regulation, cancer cells, and cell death.

MODULE V **(10 hrs)**

Cell Biology Techniques: Cell Isolation (plants and Animals), Microscopy and Micrometry: Fixed and live-cell imaging, Radioisotopes, Fluorescent Probes/Dyes as tools to study cellular functions, basics of FACS.

BIO 10302- CELL BIOLOGY LAB **(2C=96 hrs)**

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe and identify various stages of mitosis and meiosis	Understand and Remember
C.O. 2: Differentiate various types of blood cells	Analyze
C.O. 3: Differentiate various types of animal cells (organ-specific)	Analyze
C.O. 4: Differentiate various types of plant tissues	Analyze
C.O. 5: Evaluate the various stages of Mitosis and Meiosis	Evaluate

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x			x		
C.O.2					x	
C.O.3					x	
C.O.4					x	
C.O.5						x

1. Staining and observation of various organelles under the microscope
2. Imaging of Lampbrush and polytene chromosomes
3. Stages of Mitosis (Onion tip) and meiosis
4. Blood smear preparation and its analysis.
5. Imaging of various murine cell types: Epithelial cells, endothelial cells, neuronal cells, immune cells.
6. Identifying permanent tissues from plant sections (parenchyma, collenchyma, sclerenchyma, xylem vessels)
7. Identifying apoptotic and necrotic cells by the cell staining procedure

REFERENCES:

1. Campbell Biology, 10th Edition. Jane B. Reece, Lisa A. Urry, Michael L. Cain, Steven A. Wasserman, Peter V. Minorsky, Robert B. Jackson
2. Biology: A Global Approach (Paperback) by Jane B. Reece, Steven A. Wasserman 3) Molecular Biology of Gene: Watson et al.,
3. Molecular Cell Biology: By Darnell, Lodish, Baltimore
4. Concepts of Genetics William S Klug and M. R. Cummings, Gerald Karp, Cell Biology
5. Wayne M. Becker et al., World of the Cell
6. Bruce Alberts et al., Essential Cell Biology 4th Edition
7. Richard Goldsby and Thomas J Kindt, Kuby Immunology
8. Cooper, Geoffrey M., and Robert E. Hausman. 2009. *The cell: a molecular approach*. Washington, D.C.: ASM Press.
9. De Robertis & De Robertis: Cell & Molecular Biology, Lea & Febiger, 1987

SEMESTER IV

BIO 10401- GENETICS AND MOLECULAR BIOLOGY (3C= 48hrs)

Course Description: This course aims to provide an overview of genetics starting from the work of Mendel to the current understanding of various phenomena like recombination, transposition, sex determination and mutations. The course will help in building sound fundamental knowledge of the principles of genetics, to be used as a stepping stone for higher studies and research in this field. The course also aims to provide students with an introduction of the underlying molecular mechanisms of various biological processes in cells and organisms. The study primarily involves learning about the structure and synthesis of deoxyribo and ribo-nucleic acids, the formation of proteins, and the regulation of gene expression. The course aims to develop a basic understanding of molecular biology techniques and their applications

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1:Describe the basic principles of inheritance with examples	Understand
C.O. 2: Differentiate the basic structures of DNA and RNA	Analyze
C.O. 3: Explain the mechanisms of mutations, the causative agents and the harmful impact of various chemicals and drugs being used in day-to-day life.	Understand
C.O. 4: Predict the inheritance pattern of heredity based on classical genetics	Apply
C.O. 5: Discuss the DNA replication machinery in prokaryotes and eukaryotes.	Understand
C.O.6: Explain the mechanism of the flow of genetic information in prokaryotes and eukaryotes	Understand
C.O.7: Explain genetics of inheritance and apply	Apply
C.O.8: Calculate the concentration of DNA and RNA by spectrophotometric methods.	Analyze

MAPPING of CO’s and PO’s

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4		x				
C.O.5	x					
C.O.6	x					
C.O.7		x				
C.O.8					x	

MODULE I **(10 hrs)**

Mendelian Genetics- Mendelian principles, the concept of traits & alleles, monohybrid and dihybrid crosses, back cross and test cross and Mendel’s success, Modified Mendelian ratios; Incomplete dominance, Recessive and Dominant epistasis, Complementary genes, Duplicate gene, Duplicate dominant genes and Inhibitory factor. Multiple Alleles-General account. ABO blood group in man. Rh factor. Quantitative characters- quantitative inheritance, polygenic inheritance, cytoplasmic inheritance.

MODULE II **(10 hrs)**

Linkage and crossing over- Linkage and its importance, linkage and independent assortment. Complete and incomplete linkage. Crossing over – a general account, two-point and three-point test crosses. Determination of gene sequence. Interference and coincidence. Mapping of chromosomes (recombination mapping) and complementation analysis. Conjugation, transduction and transformation. Sex determination- Sex chromosomes, the chromosomal basis of sex determination in Drosophila and humans. Pedigree analysis.

MODULE III **(10 hrs)**

Introduction: history, development and scope of molecular biology. DNA as the genetic material, Griffith's experiment, Avery, Mac Leod and Mc Carty, experiment, Hershey & Chase's experiment. Structure of nucleic acids - Watson - Crick model of DNA, DNA replication in prokaryotes and eukaryotes. Semi-conservative method. Replication machinery and mechanism, enzymes involved in DNA replication. Arrangement of DNA in a chromosome- Nucleosome structure. Modification and repair of DNA. Different types of DNA and RNA.

MODULE IV **(8 hrs)**

Gene Expression: One gene-one enzyme hypothesis, one gene-one polypeptide hypothesis, central dogma hypothesis, colinearity of genes and gene products. RNA: structure & types, Genetic code - features and wobble hypothesis. Contributions of Nirenberg and his associates, Khorana and his associates. Transcription of RNAs and post-transcriptional modifications & reverse transcription and PCR. Translation and post-translational modification of proteins

MODULE V **(10 hrs)**

Gene regulation in prokaryotes; operon concept - Lac operon and Trp operon. Regulation of eukaryotic gene expression. Level of control of gene expression, transcriptional factors, regulation of RNA processing, mRNA translation, mRNA degradation & protein degradation control, epigenetics.

BIO 10402- GENETICS AND MOLECULAR BIOLOGY LAB (2C=96 hrs)

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1:Describe the basic principles of inheritance with examples	Understand
C.O. 2: Predict the inheritance pattern of heredity based on classical genetics	Analyze
C.O. 3: Stain barbodies from cheek cells and visualize to identify barbodies	Apply and Analyze
C.O. 4: Analyze chromosomes by karyotyping	Analyze
C.O. 5: Explain semiconservative replication of DNA using photographs	Understand
C.O.6: Explain the mechanism of flow of genetic information in prokaryotes and eukaryotes	Understand
C.O.7: Predict the GC content of DNA	Analyze
C.O.8: Calculate the concentration of DNA and RNA by spectrophotometric methods.	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3		x			x	
C.O.4					x	
C.O.5	x					
C.O.6	x					
C.O.7					x	
C.O.8					x	

Genetics

1. Monohybrid cross and Dihybrid cross using Pea plant & Drosophila
2. Gene interactions
    a. Recessive epistasis 9: 3: 4.
    b. Dominant epistasis 12: 3: I
    c. Complementary genes 9: 7
    d. Duplicate genes with cumulative effect 9: 6: 1
    e. Inhibitory genes 13: 3
    f. Duplicate dominant gene 15: 1
    g. Comb pattern in poultry 9:3: 3:1

3. Barbody staining from cheek cells
4. Preparation of human karyotype and study of chromosomal aberrations with respect to number, translocation, deletion, etc. from the pictures provided.
5. Pedigree analysis- Blood Groups, Free hanging earlobes, Widow's Peak, Rolling of the tongue, color blindness

Molecular Biology

1. Study of semiconservative replication of DNA through micrographs/schematic representations.
2. Practice problems in molecular biology-based on Chargaff's rule, DNA structure and replication.
3. Model making using balls and sticks-Nucleic acids
4. Operon, inducible gene expression by colour
5. DNA isolation
6. PCR amplification of DNA (Demo)
7. Preparation of Nucleic Acid models
8. Electrophoretic separation of Nucleic Acid/Proteins

REFERENCES

1. Alberts, B., Johnson, A., Walter, P., Lewis, J., Raff, M., & Roberts, K. (2008). Molecular cell biology. New York: Garland Science.
2. Lodish, H., Berk, A., Darnell, J. E., Kaiser, C. A., Krieger, M., Scott, M. P. & Matsudaira, P. (2008). Molecular cell biology. Macmillan.
3. Lewin, B., Krebs, J. E., Goldstein, E. S., & Kilpatrick, S. T. (2014). Lewin's Genes XI. Jones & Bartlett Publishers.
4. Cooper, G. M., Hausman, R. E., &Hausman, R. E. (2000). The cell: a molecular approach (Vol. 2). Washington, DC: ASM press.
5. Hardin, J., Bertoni, G. P., &Kleinsmith, L. J. (2017). Becker's World of the Cell. Pearson Higher Ed.
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SEMESTER V

BIO 10501- PLANT DIVERSITY –I
(Algae/Fungi/Bryophytes/Pteridophytes/Paleobotany) (3C= 48 hrs)

Course description: The course will cover the diversity, life forms, life cycles, morphology and importance of algae and various fungal groups and their association (lichens). The concept of phytopathology, plant diseases, causal organisms and their control will also be covered. This course aims at making familiarity with special groups of plants-Bryophytes and pteridophytes, joined together by a common feature of sexual reproduction involving antheridia and archegonia. As these groups are primitive, the palaeobotanical fossil forms are also included to have an evolutionary outlook. Study of morphology, anatomy, reproduction and developmental changes therein through typological study should create a knowledge base in understanding plant diversity, economic values, the taxonomy of lower groups of plants.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain why fungi is treated as a separate kingdom and not included in the plant and animal kingdom	Understand
C.O. 2: Classify algae, fungi, bryophytes, pteridophytes	Understand
C.O. 3: Diffrentiate fungi, lichens,bryophytes and pteridophytes based on morphology	Analyse
C.O. 4: Identify various plants and their organization in nature through field trips	Remember
C.O. 5: Collection and conservation of plant samples	Understand
C.O. 6: Discuss the significance of paleobotany in terms of understanding the evolution and emergence of plant diversity	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3					x	
C.O.4	x					
C.O.5	x					
C.O.6	x					

MODULE I **(10 hrs)**

Algae: Classification (F.E Fritsch), Principles and modern trends in the taxonomy of algae. Morphology, anatomy, life cycle and reproductive biology of a) Cyanophyceae-Nostoc b) Chlorophyceae-Chlorella, Volvox, Oedogonium and Chara c) Xanthophyceae-Vaucheria d) Bacillariophyceae-Pinnularia e) Phaeophyceae-Sargassum f) Rhodophyceae- Polysiphonia. Contributions of Indian Algologists. Economic importance of algae. Applied aspects: Biofuel production, food supplements, pharmaceutical industries, algal blooms, commercial cultivation of algae.

MODULE II **(10 hrs)**

Fungi: Salient features, Morphology, reproduction, life cycle, evolutionary trends. Distinguishing features of fungi and why is it grouped in a separate kingdom, Classification based on Ainsworth. Distinguishing characters of different classes of fungi representing the following genera, Myxomycotina-General characters, Phycomycetes-Phytophthora, Ascomycetes-Penicillium & Xylaria, Basidiomycetes-Agaricus & Puccinia, Deuteromycetes-Cercospora. Economic importance of Fungi, Fungi as a pathogen, brief account of the following fungicides-Bordeaux mixture, Lime sulfur, Tobacco devotion, Neem cake, and oil
Lichens: General account; the structure, reproduction and life cycle of Usnea, and economic importance

MODULE III **(10 hrs)**

Bryophytes: classification- general account, Study of habit, thallus organization, vegetative and sexual reproduction and alternation of generation of the following types (Developmental details are not required), Type study: *Riccia, Marchantia, Anthoceros and Funaria*. Economic importance of Bryophytes

MODULE IV **(10 hrs)**

Pteridophytes: Classification, General characters, morphological and anatomical features, life cycle and reproductive biology, Type study: *Psilotum*, *Selaginella*, *Pteris* and *Marsilea,* Stelar evolution in Pteridophytes, Economic importance of Pteridophytes.

MODULE V **(8 hrs)**

Paleobotany: Geological time scale, Fossil and fossil formation, types of fossils, fossil age calculation methods, the importance of fossils, Fossil Pteridophytes- *Rhynia,* Lepidodendron, Lepidocarpon. Fossil gymnosperms-*Lygnopteris.*

REFERENCES

1. Chopra RN and P. K. – Biology of Bryophytes - Wiley Eastern Ltd. New Delhi
2. Parihar N.S. – An introduction to Bryophyta - Central Book Depot. Allahabad
3. Vasishta B. R. - Bryophyta - S. Chand and Co. New Delhi
4. Coulter. J. M. - and Chamberlain C. J. (1958) – Morphology of Gymnosperms - Central Book Depot, Allahabad
5. Gupta V.K. and Varshneya U. D (1967) – An Introduction to Gymnosperms – Kedarnath, Ramnath – Meerut.
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7. Sporne K. R. (1966) - Morphology of Pteridophytes - Hutchin University Library London
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9. Vashista B. R. (1993) - Pteridophyta – S. Chand and co. New Delhi
10. Vashista B. R. (1993) Gymnosperms - S. Chand and co. New Delhi
11. Andrews H.N. (1967) - Studies on Palaeobotany – C. J. Felix.
12. Arnold C. A (1947) - Introduction to Palaeobotany - McGraw Hill Co. New Delhi.

BIO 10502- NON-CHORDATA **(C=48 hrs)**

Course description: The course will help the students to understand the features of Kingdom Animalia and systematic organization of the animals based on their evolutionary relationships, structural and functional affinities. The course will also make the students aware of the characteristic morphological and anatomical features of diverse animals; the economic, ecological and medical significance of various animals in human life; and will create interest among them to explore the animal diversity in nature.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Discuss the importance of systematics and taxonomy of animals.	Understand

C.O. 2: Compare the adaptive features of non-chordates living in varied habits and habitats.	Analyse
C.O. 3:Calssify non-chordates as per their distinguishing features.	Understand
C.O. 4: Examine the anatomy of different classes of non-chordates that enables survival advantages in their habitat	Analyse
C.O. 5: Identify various non-chordates based on systematics	Remember
C.O. 6: Improve collaborative learning and communication skills through practical sessions, teamwork, group discussions, assignments and projects.	Apply

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4					x	
C.O.5	x					
C.O.6		x				

MODULE I **(10 hrs)**

Basis of classification of multicellular animals: Cleavage; Germ layers; Symmetry; Body cavity; Concept of Protostomia *vs.* Deuterostomia.

MODULE II **(10 hrs)**

General characteristics and classification (up to Class/subclass level) of Major Phyla: Protozoa; Porifera; Cnidaria; Ctenophora; Platyhelminthes, Annelida, Arthropoda; Mollusca, Echinodermata.

MODULE III **(10 hrs)**

A general account of structure and reproduction of *Paramecium*; *Sycon*; *Obelia*; *Aurelia*; Planaria (*Dugesia*); *Fasciola*; *Hirudinaria*; *Pila*; Prawn; Starfish: *Peripatus*; *Limulus*; *Balanoglossus*.

MODULE IV **(10 hrs)**

Concept of Minor Phylum and their importance in the study of non-chordate evolution; General characteristics of Aschelminthes (Rotifera, Acanthocephala, Nematoda, Nematomorpha, Priapulida, Kinorhyncha, Gastrotricha), Ectoprocta; Chaetognatha; Echiura, Sipunculida, Pogonophora; Lophophorata (Phoronida, Brachiopoda, Bryozoa); Hemichordata

MODULE V **(8 hrs)**

Reproduction in Protozoans; Theories on the origin of Metazoa; Canal system in sponges; Metagenesis in cnidarians; Coral and coral reefs; Nephridial system in annelids; Trochophore larva and its evolutionary significance; Shell in molluscs; Water vascular system in echinoderms; Larval forms of Echinoderms and their significance.

REFERENCES

1. Barnes: The invertebrates (3rd ed. 2001, Blackwell)

3. Barrington: Invertebrate Structure and Function (1967, Nelson)
4. Moore: An introduction to the invertebrates (2001Cambridge)
5. Ekambaranath Ayar: A manual of Zoology, Part I – Invertebrata, (1973, S. Vishwanathan)
6. Kotpal, Agarwal and Khetrapal: Modern Textbook of Zoology: Invertebrate, (1976, Rastogi)
7. Marshall: Parker and Haswell Textbook of Zoology, Vol. I (7th ed. 1972, Macmillan)
8. Nigam: Biology of Non-chordates (1985, S. Chand)
9. Jordon and Verma: Invertebrate Zoology (1995, S. Chand)
10. Millar and Harley: Zoology (6th ed. 2005, Brown)
11. Garey, J. R. and Schmidt-Rhaesa, A. The Essential Role of "Minor" Phyla in Molecular Studies of Animal Evolution. AMER. ZOOL., 38:907-917 (1998).

BIO 10503- PLANT DIVERSITY II (Gymnosperms and Angiosperms) (3C= 48 hrs)

Course description: The course aims to provide knowledge of gymnosperms and angiosperms. The economic importance of diverse plants that offer resources to human life will be covered. The course also aims to provide knowledge of the plants used by the local communities, tribals, ethenic groups, their nutritive and medicinal value.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the general characteristics of gymnosperm and angiosperm.	Understand
C.O. 2: Differentiate between gymnosperms and angiosperms based on morphological character	Analyse
C.O. 3: Compare the diversity among plants based on morphology, anatomy, life cycle.	Analyse
C.O. 4: Identify the local flora having economic and ethnobotanical importance for exploring the natural products with potential medicinal implications	Remember
C.O. 5: Classify various plants based on pollen architecture	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4	x					
C.O.5	x					

MODULE I **(10 hrs)**

Gymnosperms: Classification, general features, morphology, anatomy, life cycle and reproductive biology of Cycadopsida-*Cycas,* Coniferopsida-*Pinus* and Gnetopsida-*Gnetum*. Evolutionary trends in gymnosperms and their economic importance.

MODULE II **(10 hrs)**

Angiosperms: Principles and importance of taxonomy, Herbarium technique, BSI and ICBN. Systems of classification. Outline classification of Bentham & Hooker and Cronquist. APG systems of classification. The concept of taxon and Taxonomic hierarchy, plant nomenclature. A brief reference to the citation of the author. Chemotaxonomy.

MODULE III **(10 hrs)**

Morphology: Morphology of root, stem, leaves and inflorescence. Floral morphology and structure, the symmetry of flower, aestivation, placentation; floral diagram and floral formula, Fruit types: simple, aggregate and multiple. Seeds: albuminous and exalbuminous. Palynology: Pollen architecture, Pollen transfer, Pollen – pistil interaction. Pollination and its types. Pollen allergy, palynological calendars and pollen analysis of honey.

MODULE IV **(8 hrs)**

Economic botany: Binomial, family and morphology of useful parts of Maize, soya bean, sugarcane, cocoa, tea, pepper, cardamom, potato, banana, mango, cashew nut, tomato, vinca, opium, teakwood.

MODULE V **(10 hrs)**

Ethnobotany: Ethnobotany and Folk medicines. Ethnobotany in India, Methods to study ethnobotany -Fieldwork, Herbarium, Ancient Literature, Archaeological findings, temples and sacred places. Applications of Ethnobotany: Medicinal plants of tribals with reference to Thuthi, Kadukkai, Perandai, Avarai, Kandankathari, Oomathai, Veliparuthi, Asparagus and Boerhaavia. Legal aspects-biopiracy, IPR & traditional knowledge,

REFERENCE

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3. Verma V, 2009 Text Book of Economic Botany; Ane Books Pvt. Ltd.
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8. Singh. G. 1999. Plant Systematics: Theory and practice Oxford & IBH Pvt, Ltd.New Delhi.
9. Nordenstam. B.., El-Gazaly, G. and Kassas. M. 2000. Plant Systematics for 21st Century
10. S.K. Jain. Glimpses of Ethnobotany. Oxford and IBH Publishing Company, New Delhi.

BIO 10504- CHORDATA **(3C= 48 hrs)**

Course description: The course is designed to provide the scope and historical background of chordates. It will impart knowledge regarding basic concepts of the origin of chordates and make the students understand the characteristics and classification of animals with notochord. An adequate explanation to the students regarding various mechanisms involved in the thriving survival of the animals within their geographic realms will create interest among students.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1:Describe different classes of chordates, level of organization and evolutionary relationship between different subphyla and classes.	Understand
C.O. 2: Differentiate the members of each class based on morphology, anatomy, life cycle and other distinguishing features.	Analyse
C.O. 3: Identify the similarities and differences in life functions among various groups of animals in Phylum Chordata.	Remember
C.O. 4: Compare the members based on anatomical features in relation to function (circulatory, nervous and skeletal system of chordates).	Analyse
C.O. 5: Discuss the pattern of vertebrate evolution, organization and functions of various systems.	Remember
C.O. 6: Evaluate the survival advantages of chordates based on adaptive features in various habitat (marine, freshwater and terrestrial ecosystems)	Evaluate
C.O. 7: Explain the characteristic features of various structures in relation to function	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4					x	
C.O.5				x		
C.O.6						x
C.O.7	x					

MODULE I **(10 hrs)**

General characteristics, classification of the following up to sub-classes/ orders with examples and affinities of the following: Protochordata (Urochordata, Cephalochordata); Cyclostomata; Pisces; Amphibia; Reptilia; Aves; Mammalia; Origin of vertebrates, lungfishes; Amphibians, birds and mammals.

MODULE II **(10 hrs)**

Functional morphology of *Branchiostoma*, *Petromyzon*; Mullet, Frog; *Calotes*, fowl and rabbit.

MODULE III **(8 hrs)**

Adaptive radiation in vertebrates: Aquatic; Terrestrial; Aerial; Arboreal; Fossorial.

MODULE IV **(10 hrs)**

Evolution of aortic arches; jaw suspensorium; respiratory organs (gills, skin, lungs, air sacs, accessory respiratory organs), kidney, skull in reptiles; brain (cerebral hemisphere, cerebellum).

MODULE V **(10 hrs)**

General considerations of integumental derivatives Scales, feathers, hair, claws, nails, hoofs, horns, antlers, glands), stomach in ruminants, Parental care in amphibians; snake venom; bird migration; flightless birds; dentition in mammals.

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3. Nigam: Biology of Chordates (1983, S Chand)
4. Harvey *et.al*: The Vertebrate Life (2006)
5. Colbert *et.al*: Colbert's Evolution of the Vertebrates: A History of the Backboned Animals through time (5th ed, 2002, Willey-Liss)
6. Hildebrand: Analysis of Vertebrate Structure (4th ed, 1995, John Willey)
7. Jordan &Verma: Chordate Zoology (1998, S.Chand)
8. McFarland *et.al*: Vertebrate Life (1979, Macmillan Publishing)
9. Parker & Haswell: Textbook of Zoology, Vol. II (1978, ELBS)
10. Romer & Parsons: The Vertebrate Body (6th ed 1986, CBS Publishing Japan)
11. Sinha, Adhikari & Ganguli: Biology of Animals Vol.II (1988, New Central Book Agency)
12. Young: The Life of Vertebrates (3rd ed 2006, ELBS/Oxford)
13. Young: The Life of Mammals (1975 Clarendon)

BIO 10505- PLANT LAB 1 **(2C= 96 hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Identify and Evaluate the vegetative and reproductive structures of fungi, Algae, Bryophytes, and Pteridophytes	Remember/Evaluate
C.O. 2: Apply taxonomic protocols and Classify algae, fungi, bryophytes, pteridophytes	Understand /Apply
C.O. 3: Diffrentiate fungi, lichens,bryophytes and pteridophytes based on morphology	Analyse
C.O. 4: Identify various plants and their organization in nature through field trips	Remember

C.O. 5: Collection and conservation of plant samples	Create
C.O. 6: Use bioinformatics tools for DNA/gene analysis of plants and Interpret the phylogenetic relationships	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					x
C.O.2	x	x				
C.O.3					x	
C.O.4				x		
C.O.5						x
C.O.6					x	

Plant Diversity (Algae/Fungi/Bryophytes/Pteridophytes/Paleobotany)

1. Study of vegetative and reproductive structures of Nostoc, *Chlamydomonas* (electron micrographs), *Oedogonium*, *Vaucheria*, and *Polysiphonia* through permanent slides.
2. *Rhizopus* and *Penicillium*: Asexual stage from temporary mounts and sexual structures through permanent slides.
3. *Phytophthora*: Specimens/photographs
4. *Puccinia*: Uredial and telial stage TS, stage identification with permanent slides.
5. *Agaricus*: Specimens of button stage and full-grown mushroom; LS of gills.
6. Lichens: Study of growth forms of lichens (crustose, foliose and fruticose)
7. *Riccia*- Habit- V.S of the thallus, VS through archegonia, antheridia and sporophyte
8. *Marchantia*- Habit, thallus VS, male receptacle and female receptacle-entire and VS, thallus gemma-entire and VS, Sporophyte VS
9. *Anthoceros:* Habit- VS of thallus and sporophyte
10. *Funaria*- Habit V.S. of the archegonial cluster, Antheridial cluster and Sporophyte
11. Psilotum -External features, Stem T.S., Synangium T.S
12. *Selaginella* - Habit, stem & rhizophore T.S, V.S of strobilus
13. *Pteris* - Habit, Rachis T.S Sporophyll T.S, Prothallus
14. *Marselia* - Habit, Rhizome and Petiole T.S, Sporocarp T. and V.S
15. Identification and critical notes on fossil forms (Fossil slides).

Gymnosperms and Angiosperms

1. *Cycas*- T.S of leaf, T.S. of coralloid root, Male and female cone, ovule (LS)
2. *Pinus*- T.S. of the stem, T.S. of needle, male and female cone VS
3. *Gnetum*-Habit, stem T.S, (young and mature), leaf T.S, male and female strobilus, V.S of the male and female cone, ovule V.S and seed.
4. Study on various types of inflorescences, flowers and fruits with a vivid record of practical work.
5. Draw a labeled diagram of the habit, floral parts, L S of flower, T S of ovary, floral diagram, floral formula and describe the salient features of the member in technical terms of the families: Annonaceae, Rutaceae, Cucurbitaceae, Rubiaceae, Asteraceae, Sapotaceae, Asclepiadaceae, Verbenaceae, Euphorbiaceae, Orchidaceae and Poaceae.

6. Students must submit practical records, Herbarium sheets (25 Nos:) and Field books at the time of practical examination.
7. Identify the economic products obtained from the plants mentioned under Economic Botany
8. Critical notes on plants of ethnobotanical relevance mentioned in the syllabus.

Biostatistics and Bioinformatics

1. To perform a "two-sample t-test" for a given set of data
2. To learn graphical representations of statistical data with the help of computers (e.g. MS Excel).
3. Accessing different biological databases
4. Retrieval of nucleotide and protein sequences from the databases.
5. To perform pair-wise alignment of sequences (BLAST) and interpret the output
6. Generation of a phylogenetic tree and its analysis
6. Translate a nucleotide sequence and select the correct reading frame of the polypeptide from the output sequences
7. Predict the structure of a protein from its amino acid sequence.

BIO 10506- ANIMAL LAB 1 **(2C= 96 hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Identify and Analyze various anatomical structures of non-chordates and chordates (mouthparts, respiratory system, appendages etc)	Analyze
C.O. 2: Differentiate the members of each class based on morphology, anatomy, life cycle and other distinguishing features.	Analyse
C.O. 3: Identify the similarities and differences in life functions among various groups of animals in Phylum Chordata.	Remember and Analyze
C.O. 4: Compare the members based on anatomical features in relation to function (circulatory, nervous and skeletal system of chordates) of non-chordates and non-chordates.	Analyse
C.O. 5: Predict protein sequence based on gene sequence	Analysis
C.O. 6: Design analogues of enzyme inhibitors / catalytic sites of enzyme to aid in *in silico* drug discovery	Create
C.O. 7: Explain the characteristic features of various structures in relation to function	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6

C.O.1					x	
C.O.2					x	
C.O.3				x	x	
C.O.4					x	
C.O.5					x	
C.O.6			x			
C.O.7	x					

Non-Chordata

1. Nereis - parapodium
2. Earthworm – body setae, nervous system
3. Scales of butterfly wing
3. Cockroach – mouth parts /salivary gland/nervous system
4. Honey bee – mouthparts/mosquito - mouthparts
5. Prawn – appendages (Any Three- Maxillipeds1,2,3, Chelate leg, First abdominal appendage) nervous system
6. Spot Identification: Taxonomy Identification, Classification up to class and a brief note of the following specimens.

I. Protista – Actinophrys, Noctiluca, Paramecium, Opalina – any 2
II. Phylum Porifera – Euplectella, Spongilla- any 1
III. Phylum Cnidaria – Hydra, Obelia, Physalia, Aurelia, Sea anemone, Madrepora – any 3
IV. Phylum Nematoda – Ascaris- male and female (entire)
V. Phylum Platyhelminthes – Bipalium, Fasciola, Taenia solium – any 1
VI. Phylum Annelida – Earthworm, Nereis, Leech, Aphrodite, Arenicola – any 1
VII. Phylum Onychophora – Peripatus
VIII. Phylum Arthropoda – Cockroach, Limulus, Eupagurus, Sacculina, Honeybee, Lepisma, Scorpion – any 3
IX. Phylum Mollusca – Chiton, Pila, Xancus, Dentalium, Perna, Mytilus, Teredo, Sepia, Octopus. – any 2
X. Phylum Echinodermata – Starfish, Brittle star, Sea urchin, Sea cucumber, Sea lily – any 2

Chordata

1. *Branchiostoma*- External features; Mounting of the oral hood, velum and pharyngeal wall Study of the following slides: T.S. through the oral hood, midgut diverticulum, pharyngeal region, gonads and post oral region of the intestine; study of *Pyrosoma, Salpa, Doliolum*

2. Mounting of cycloid and ctenoid scales; mounting of chromatophores of fish;
study of different types of feather: Contour, filoplume and down feathers

3. Vascular system- Heart and afferent and efferent branchial vessels of Mystus/ *Cirrhinus sp.;*
Arterial and venous systems of rat

4. Respiratory system: Accessory respiratory organs of *Heteropneustes, Channa, Clarias*

5. Nervous system of a fish

6. Histology of tooth, tongue, esophagus, stomach, intestine, pancreas, liver, spleen, kidney cartilage, bone of mammals

7. Study of the following museum specimens/animals from the Zoo or field

1. Cyclostomata: *Petromyzon*, *Myxine*
2. Chondrichthyes: *Scoliodon*, *Sphyrna*, *Torpedo*, *Pristis*

3. Osteichthyes: *Protopterus, Exocetus, Hippocampus, Syngnathus, Tetradon, Diodon, Amia, Anabas, Ophiocephalus, Clarias, Heteropneustes, Catla, Labeo,*
4. Amphibia: *Ichthyophis, Axolotl larva, Amphiuma*,Proteus, *Pipa*, Rhacophorais Hyla
5. Reptilia: Turtle, *Chameleon, Draco, Uromastix, Varanus, Calotes, Iguana, Mabuya, X Natrix, Naja, Vipera, Alligator*
6. Aves: *Apteryx, Struthio, Aptenodytes, Francolinus, Tyto alba, Dinopium, Milvus, Corvus, Pavo, Eudynamys, Passer, Psittacula, Anas, Grus*
7. Mammalia: *Ornithorhynchus, Tachyglossus, Macropus, Manis, Erinaceus, Pteropus, Lemur, Loris, Bradypus, Phoca, Lutra, Equus caballus, Camelus, Capra, Bos*

Animal Forms and Functions

1. Study and mounting of cephalic appendages of Palaemon
2 Dissection of the digestive system of Palaemon and mounting of Hastate plate
3 Study of mouthparts of *Periplaneta americana*
4 Dissection of the alimentary canal of *Periplaneta americana*
5. Internal transport: Dissection of afferent and efferent branchial arteries of *Mystus*
6. Nervous system, receptors and sense organs
7. Dissection of the nervous system of Palaemon
8. Mounting of statocyst of Palaemon
9. Dissection of 5th, 7th, 9th, and 10th cranial nerves of Mystus
10. Permanent preparation of gemmules of sponges
11.Study of the following through permanent slides/museum specimens: Conjugation in *Paramecium*, Sporocyst of *Fasciola* with developing *Redia*, *Cercaria* and *Metacercaria* larvae, *Trochophore* larva, *Nauplius* and *Zoea* larvae, *Bipinnaria*, *Auricularia* and *Pluteus* larvae, *Tornaria*, *Ammocoetes* and *Tadpole* (frog); Axolotl

BIO 10507- OPEN END LAB I (2C= 96 hrs)

BIO 10508- BIOSTATISTICS AND BIOINFORMATICS (2C= 32 hrs)

Course description: This course offers an overview of fundamental concepts of d Biostatistics and Bioinformatics. An interdisciplinary program, it emphasizes the integration of Computer Science with Biology and introduces the students to various computational methods and software tools based on biostatistics for understanding biological databases, gene sequence alignments, gene annotation, protein structure predictions, drug discovery, molecular phylogeny, metagenomics, etc.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the basic concepts of Bioinformatics and Biostatistics and their various applications in different fields of biological sciences	Understand
C.O. 2: Calculate the variability (standard deviation, standard error, coefficient of variance) and hypothesis testing (Z-test, t-Test, chi-square test)	Analyse

C.O. 3: List various biological databases – nucleic acids, protein sequence, metabolic pathways and small molecule	Remember
C.O. 4: Analyse gene sequence and pinpoint mutations	Analyze
C.O. 5: Predict protein sequence based on gene sequence	Apply
C.O. 6: Interpret the phylogenetic relationships	Apply
C.O. 7: Design analogs of enzyme inhibitors / catalytic sites of enzyme to aid in *in silico* drug discovery	Create

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3				x		
C.O.4					x	
C.O.5		x				
C.O.6		x				
C.O.7			x			

MODULE I **(8 hrs)**

Introduction to Biostatistics: Variable and-attribute; Population vs. Sample; Arrangement of data; Frequency distribution. Graphical presentation of data: Line diagram; Bar diagram; Pie chart; Histogram. Measures of central tendency: Arithmetic mean; Mode; Median. Measures of dispersion: Variance; Standard deviation; Standard error of the mean; Testing of hypothesis and goodness of fit: Null hypothesis, Level of significance, Probability, Normal distribution, Error of inference, Student's t-test, Chi-square test.

MODULE II **(5 hrs)**

Overview of Information Technology: features of the modern Personal Computer and Peripherals computer networks and Internet. Introduction to Operating System. DOS/Windows. Linux. Purchase of technology, license. guarantee. warranty. Definition, Nature & Scope of Bioinformatics.

MODULE III **(6 hrs)**

Computational Biology; Key Bio-sequences in Molecular Biology - DNA, RNA and Amino acid sequences. Popular Databases in Bioinformatics – NCBI, DDJB, PDB, OMIM; BLAST & FASTA sequence file formats, Approach of Comparative Biology based on sequence comparison - The basic idea of sequence comparison (algorithms not required) - idea of scoring matrices

MODULE IV **(6 hrs)**

The Blast search engine - important features - Idea of Multiple sequence alignment. Proteomics: Basic ideas of Protein Structure prediction- Concept of Homology Modeling- Idea of Molecular Phylogenetics - 'advantages and computational procedure (only description of the use of a package such as Phylip). Basic concepts of computer Aided, Drug. Discovery.Autodock, ADME, Structure-function relationship.

MODULE V **(7 hrs)**

Bioinformatics tools: (i) Molecular Visualization Software - Rasmol (Basic features only)- (ii) ORF finding (iii) gene finding, (iii) BLAST (iv) Hydrophobicity Prediction (v)Single Nucleotide Polymorphism (SNP) prediction using GENSNIP, Central Drug Research Institute

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2. Sokal & Rohif(1973) Introduction to Biostatistics -Toppan Co-Japan
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4. Arthur. M. Lesk (2000) Introduction to Bioinformatics, Oxford publishers.
5. Bajpai, P. K. (2008) Biological instrumentation and methodology. S. Chand and Company Ltd.
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11. Graeme. D. Ruxton and Nick Colegrave. (2006) Experimental design for the life sciences, 2nd edition. Oxford University Press.
12. Gurumani. Research Methodology. M.J.P.Publishers, Chennai, 600 005
13. Keith Wilson and John Walera. (2008) Principles and techniques of biochemistry and Molecular Biology. Cambridge University Press.

BIO 10509- ANIMAL FORMS AND FUNCTIONS (2C= 32 hrs)

Course description: This course aims to provide a thorough knowledge of structural details and a comparative account of the different organ systems of the body from lower to higher vertebrates, and protochordate, thus enabling them to appreciate the incredible vertebrate diversity. It helps students propose possible homology between structures, and understand how they evolved as the vertebrates dwelled in different habitats. The structural modifications of the digestive, circulatory, respiratory and skeletal systems relate to the distribution of animals in their different comfort zones of habitat and ecological niches.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain comparative account of the different vertebrate systems	Understand
C.O. 2: Describe the evolution of the heart, modification in aortic arches, the structure of respiratory organs used in aquatic, terrestrial and aerial vertebrates; and digestive system and its	Understand

anatomical specializations with respect to different diets and feeding habits.	
C.O. 3: Discuss the evolution of the brain, sense organs and excretory organs to a complex, highly evolved form in mammals	Understand
C.O. 4: Evaluate the structure and functions relationship of animals which furnish with survival advantages in a habitat	Evaluate

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4						x

MODULE I **(6 hrs)**

Modes of Feeding and Digestion: Feeding mechanisms: suspension, deposit, cropping and sucking (herbivorous) and raptorial (carnivorous), Intracellular and extracellular digestion: food vacuole and gastrovascular cavity, Types of excretion and Mode of Excretion Open tubular: metanephridia, Closed saccular: protonephridia, Malpighian tubules and kidney.

MODULE II **(6 hrs)**

Respiratory Organs, Structure and function of gills, trachea, book lungs and vertebrate lungs.

MODULE III **(6 hrs)**

Circulatory systems: Pattern of circulation in non-chordates and chordate, hemocoel, open and closed circulatory systems, the difference in chambers, evolutionary significance.

MODULE IV **(6 hrs)**

Nervous system: Patterns of the nervous system in non-chordates, Organization of the nervous system in vertebrates: central and autonomic system, Receptors and sense organs, Phonoreception in fish and mammals, Photoreception in insects and mammals

MODULE V **(8 hrs)**

Reproduction Types of asexual reproduction: fission, regeneration and parthenogenesis, Sexual reproduction: primary and accessory sex organs and their functions

REFERENCES

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2. Nigam: Biology of Non-chordates (1997, S Chand)
3. Nigam: Biology of Chordates (1997, S Chand)
4. Parker & Haswell: Text Book of Zoology, Vol. II (2005, Macmillan)
7. Purves et al: Life-the Science of Biology, (7th ed. 2004, Sinauer)

8. Tortora and Anagnostakos: Principles of Anatomy and Physiology (6th ed. 1986, Harper & Row).
9. Schmidt Nielson: Animal Physiology (5th ed. 2005, Cambridge)
10. Hoar: General and Comparative Physiology (7th ed. 2005)
11. Arms and Camp: Biology (4th ed. 1995)

SEMESTER VI

BIO 10601- MICROBIOLOGY (3C= 48 hrs)

Course description: The main objective of this course is to give students an insight into the world of microorganisms. The paper discusses the historical developments and major milestones leading to the development of microbiology as a separate discipline of science. The students will understand the diversity, structure, evolution and impact of microbes in our day-to-day life and for the sustenance of life on Earth in general.

Learning Outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the significance of microbiology as a scientific discipline.	Understand
C.O. 2: Classify bacteria as per Bergy's manual	Understand
C.O. 3: Explain the diversity, distribution, cell structure, life cycles and economic importance of micro-organisms.	Understand
C.O. 4: Differentiate different microbes based on morphology using microscopy techniques.	Analyse
C.O. 5: Classify beneficial and non-beneficial microbes and their impact on society.	Understand
C.O. 6: Employ sterilization or decontamination procedures	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4					x	
C.O.5	x					
C.O.6		x				

MODULE I (10 hrs)

Microbiology History and scope of microbiology Bacteriology: Morphological classification, classification based on staining reaction, Ultrastructure of bacteria, Reproduction, Metabolism-

Energetics, metabolic pathways, Economic importance, Mycoplasma and Actinomycetes-General account

MODULE II **(10 hrs)**

Virology: Virus-General characteristics, nomenclature, classification, structure, chemical composition, properties and reproduction of bacteriophages and TMV, Economic importance, Viral pathogens of plants and animals, Viroids and Prions, anti-viral vaccines, viral vectors, Coronavirus and Covid19 pandemic

MODULE III **(10 hrs)**

Plant-microbe Interaction: Adverse, mutualistic and commensal relationships between plants and microbes with examples, agricultural microbiology-Rhizosphere, the role of microbes in soil fertility, Nitrogen fixation, Biofertilizers, plant pathology; Classification of plant diseases based on causative organisms and symptoms-Host parasite interaction, phytoalexins, Leaf mosaic of Tapioca, citrus Canker, Blast disease of Paddy, Root wilt of coconut

MODULE IV **(10 hrs)**

Animal Microbe interaction: Adverse, mutualistic and commensal relationships between animals and microbes with examples, Cellular, Biochemical and genomic basis of microbial colonization, Infection and pathogenesis in animals, Zoonotic Diseases-Vectors, Fungal, bacterial and viral diseases, Overview on drugs and therapeutics, bacteriocide, antibiotics, antibiotic resistance, fungicide, mode of action

MODULE V **(8 hrs)**

Physical and chemical control of microbes. Principles of antimicrobial therapy: Various methods of control of microorganisms: physical, chemical and biological. Different methods of Sterilization- moist heat sterilization, Dry heat sterilization, Filter sterilization of thermolabile substances and air, chemical sterilization, Disinfection, and antisepsis, Antimicrobials, classification and modes of action. Antimicrobial resistance and their impact

REFERENCES

1. S.A.J. Tarr (1972). Principles of Plant Pathology. Macmillan International Higher Education.
2. T. V. R. Pillay [Ed.]. (1972). Coastal Aquaculture in the Indo Pacific Region, FAO.
3. T. V. R. Pillay and Dill W. A. [Eds.] (1979). Advances in aquaculture fishing. Fishing News Books.
4. Vita I.D. [Ed.] (1993). Freshwater pond culture and management. Scientific Publishers, Jodhpur.
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12. Bradley KM, Elmore JB, Breyer JP, Yaspan BL, Jessen JR, Knapik EW, Smith JR. 2007. A major zebrafish polymorphism resource for genetic mapping.
13. Genome Biol 8(4): R55. Breder CM, Rosen DE, American Museum of Natural History. 1966. Modes of reproduction in fishes. Garden City (NY): Natural History Press. Darrow KO, Harris WA. 2004.
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15. Sex determination and sex differentiation in fish: An overview of genetic, physiological, and environmental influences. Aquaculture 208:191-364.

BIO 10602- ANGIOSPERM (ANATOMY /PHYSIOLOGY/EMBRYOLOGY) (3C=48 hrs)

Course description: The aim is to acquaint the students with the internal basic structure and cellular composition of the plant body and correlate structure with important functions of different plant parts. The course focuses on the study of various tissue systems and their development and functions in plants. The course will also provide in-depth knowledge of the flowering and fruiting, reproduction process, the role of pollinators, ovule and seed development.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the anatomical features (cells and tissues, meristem, epidermal and vascular tissue systems) in plants.	Understand
C.O. 2: Explain various aspects of growth, reproduction, and development	Understand
C.O. 3: Differentiate Angiosperms based on anatomical features and classify accordingly.	Analyze
C.O. 4: Discuss the physiology of flowering and molecular and genetic aspects of reproduction.	Understand
C.O. 5: Differentiate monocot and dicot plants	Analyse
C.O. 6: Apply the knowledge on physiological aspects of plants to improve crop productivity in extreme weather conditions	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3					x	
C.O.4	x					
C.O.5					x	
C.O.6		x				

MODULE I **(10 hrs)**

Angiosperm Anatomy: Objective and scope of plant anatomy, Permanent tissues – Definition, classification - simple, complex and secretory, Tissue systems – Epidermal tissue systems-stomata, structure and functions, Ground tissue systems & vascular tissue systems. Different types of vascular arrangements, Apical meristems & theories on the apical organization - Apical cell theory, Histogen theory, Tunica -Corpus theory.

MODULE II **(8 hrs)**

Organization of root apex in dicots & monocots. Primary structure – Root, stem and leaf [Dicot & Monocot]. Secondary growth - Root and stem- cambium, periderm formation-phellem, phellogen and phelloderm, lenticels. Anomalous secondary growth, growth hormones.

MODULE III **(10 hrs)**

Physiology: General Introduction on physiological processes of higher plants, water relations of plants, Plasmolysis and its significance, Transpiration types and its Significance anti-transpirants, Guttation and its significance, Mineral nutrition, Translocation of solute, Pathway of movement, phloem transport, electro-osmotic theory. Photosynthesis, structure and function of the chloroplast, Two pigment systems; Mechanism of photosynthesis-Light reaction, Calvin cycle, C4 cycle and photorespiration,

MODULE IV **(10 hrs)**

Embryology Structure and development of anther, the structure of mature pollen and Male gametophyte. Structure and development of ovule. Female gametophyte Monosporic (Polygonum type) Fertilization – Double fertilization - Syngamy - triple fusion - post-fertilization changes. Endosperm types - nuclear, cellular - helobial - Ruminate endosperms, the function of endosperms.

MODULE V **(10 hrs)**

Development of the embryo in Dicot and Monocot. A brief account on Polyembryony, parthenocarpy**.** Asexual reproduction: Vegetative apomixis. Adventive embryony. Non-recurrent apomixis, diplospory, apospory, parthenogenesis, androgenesis, automixis, semigamy, agamic complex.

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3. Johri B. M. 2011. Embryology of Angiosperms. Springer.
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BIO 10603- EVOLUTION AND DEVELOPMENTAL BIOLOGY (3C= 48 hrs)

Course description: This course offers a chance to students to learn about deciphering evidence ranging from fossil records to molecular data and arranges them to establish phylogenetic relationships of species, and provides a platform to understand various forces which bring about variations among populations of a species and cause them to diversify into new species. The course also focuses on Developmental Biology to provide four-dimensional thinking of students to truly understand the patterns and process of embryonic development, body plan, fate map, induction, competence, regulative and mosaic development, molecular and genetic approach for the study of developing embryo which is not necessarily shared with any other disciplines in the biological sciences.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the relationship of the evolution of various species and the environment they live in	Understand
C.O. 2: Explain the molecular events associated with the developmental process of living forms from single fertilized egg, the zygote.	Understand
C.O. 3: Discuss the stages of developmental processes that lead to the establishment of the body structure of multicellular organisms	Understand
C.O. 4: State the importance of stem cell therapy, in vitro fertilization and amniocentesis etc.	Remember
C.O. 5: Describe the evolution of man, speech, language and culture,	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4				x		
C.O.5	x					

MODULE I (10 hrs)

Biochemical and genomic evolution: The evolutionary history of proteins, Evolution of gene, gene families, molecular drive, Amino acid sequence divergence in proteins, Nucleotide sequence divergence in DNA noncoding RNA, micro RNAs, the phylogenetic utility of RNA structures, Hitchhiker's guide to evolving networks, protein-protein interaction network, the evolution of metabolic networks, and concept of molecular clock, Outline of origin of prokaryotic and eukaryotic genomes, The "C-Value paradox",

MODULE II **(10 hrs)**

Origin of Higher Categories, Origin of Metazoa, theories of origin, Origin and evolution of Trilobites, vertebrate groups- Pisces, Amphibia, Reptilia, Aves and Mammals. The evolutionary history of neural integration, endocrine systems, Hormones Phylogenetic gradualism and punctuated equilibrium, Micro and Macroevolution. Stages in Primate Evolution- Prosimii, Anthropoidea and Hominids. Factors in human origin-Hominid fossils, Cytogenetic and Molecular basis of the origin of the man-African origin of modern man-Mitochondrial Eve, Y chromosomal Adam, - early migration, hunter-gatherer societies, Evolution of human brain-communication, speech and language. Evolution of culture.

MODULE III **(10 hrs)**

Developmental Biology: Introduction theories- Preformation, Epigenesis, Recapitulation and Germplasm. Subdivisions of Developmental biology. Spermatogenesis and oogenesis, the structure of Graafian follicle, typical egg and sperm, Polarity of egg, egg envelops; classification of eggs based on different criteria. Fertilization: Agglutination, sperm penetration, activation of egg, amphimixis; physiological and biochemical changes during and after fertilization. Parthenogenesis, Cleavage, Morula formation, blastulation, blastocyst.

MODULE IV **(10 hrs)**

Cell differentiation: totipotency, pleuripotency and unipotency of embryonic cells. Determination and differentiation in embryonic development. Gene action, Drosophila as a model organism (a brief account only), Homeotic genes and Hox genes, Presumptive organ forming areas and fate maps, Gastrulation, morphogenetic movements, epiboly and emboly, the concept of germ layers, derivatives of germ layers.

MODULE V **(8 hrs)**

Human - implantation, pregnancy, parturition. Placentation in mammals - different types of placenta, functions, Teratology. Experimental embryology, developmental disorders. In vitro fertilization and embryo transfer experiments in mammals and test-tube babies, prenatal diagnosis and sex determination methods – amniocentesis chorionic villus sampling, ultrasound scanning. Embryonic and adult stem cell research and stem cell therapy.

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3. Futuyma D. J. (1998): Evolutionary Biology. Sinauer
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BIO 10604 PARASITOLOGY AND IMMUNOLOGY (3C= 48 hrs)

Course description: Parasitology will enable us to diagnose parasites correctly, understand their life cycle and control them effectively and use some of them as biocontrol agents. Parasitology; especially the study of life cycles of parasites; has helped in defying the stigmas and religious taboos for many societies making free many of the people from superstition and ill-health. The course shall surely skill the students to see, appreciate and understand the diversities of parasites in the whole spectrum of the study of life. Also, provide an overview on the immune system and its function. The course shall also make the students aware of the possible scopes of the subject which include research and applied aspects including entrepreneurial works.

Learning Outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the fundamentals of parasitology, parasitic invasion in both plants and animals; applicable to medical and agriculture aspects.	Understand
C.O. 2: Describe the measures to prevent parasitic attack, Diagnosis, Prophylaxis and Treatment of parasitic infections.	Understand
C.O. 3: Discuss the basics of immunology and List immunological components	Understand
C.O. 4: Differentiate various blood cells by microscopy	Analyze
C.O. 5: Differentiate various parasites as per morphology	Analyze
C.O. 6: Evaluate various blood cells and immune cells based on markers	Evaluate

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4					x	
C.O.5					x	
C.O.6						x

MODULE I **(8 hrs)**

Introduction to Parasitology Brief introduction of Parasitism, Parasite, Parasitoid and Vectors, Host-parasite relationship, Ecology of parasites, Population dynamics of parasite and establishment of the parasite population in the host body, the evolution of parasitism, evolution and coevolution of parasite with respect to host strategy, Important case studies in the field of Parasitology including some historical events such as the role of the mosquito control and the successful completion of the construction of the Panama canal.

MODULE II **(10 hrs)**

Parasitic Protists Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Entamoeba histolytica*, *Giardia intestinalis*, *Trypanosoma gambiense*, *Leishmania donovani*, *Plasmodium vivax*. Parasitic Platyhelminthes Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Fasciolopsis buski*, *Schistosoma haematobium, Taenia solium* and *Hymenolepis nana*.

MODULE III **(10 hrs)**

Parasitic Nematodes Study of Morphology, Life Cycle, Prevalence, Epidemiology, Pathogenicity, Diagnosis, Prophylaxis and Treatment of *Ascaris lumbricoides*, *Ancylostoma duodenale*, *Wuchereria bancrofti* and *Trichinella spiralis*. Study of the structure, lifecycle and importance of *Meloidogyne* (Root-knot nematode), Pratylencus (Lesionnematode), Parasitic Arthropoda Biology, importance and control of ticks, mites, *Pediculus humanus, Xenopsylla cheopis* and *Cimex lectularius*. Crustacean parasites. Parasitic Vertebrates A brief account of parasitic vertebrates; Cookiecutter Shark, Candiru, Hood Mockingbird and Vampire bat.

MODULE IV **(10 hrs)**

Introduction, history, development and scope, Immunity: definition, classification of immunity. Innate and adaptive, Components of Immune system: organs and tissues of the immune system. Antigens and Antibody, epitopes, antibodies (Immunoglobulins) - definition, the general structure of Ig, Ig determinants, precipitation reactions, agglutination reactions, complement fixation, neutralization, opsonization, complement system, major histocompatibility complex (MHC), types of immune responses- humoral immune response, cellular immune response, mention cytokines, define immunological memory, immunological tolerance and immune suppression

MODULE V **(10 hrs)**

Hypersensitivity/allergy and Autoimmunity: definitions, classification- types I, II and III, immunodeficiency diseases, Acquired Immune Deficiency Syndrome (AIDS); Auto immunity-definition, mechanism, mention AI diseases; transplantation immunity, graft versus host reactions, Immunization and vaccination.

REFERENCES

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4. Kuby Immunology, Richard, Thomas, Barbara, Janis, W. H. Freeman and Company [Latest edition].
5. Immuno Biology- The immune system in health and disease, Janeway, Travers, Walport and Shlomchik, Garland Science Publishing [Latest edition].
6. Essentials of Immunology, David, Brostoff and Roitt, Mosby & Elsevier Publishing[Latest edition].
7. Fundamentals of Immunology by William E. Paul, Lippincott Williams & Wilkins Publishing [Latest edition].
8. Cellular and Molecular Immunology by Abul K. Abbas, Andrew H. Lichtman, Shiv Pillai, Elsevier Publishing [Latest edition].

BIO 10605- PLANT LAB 2 **(2C= 96 hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Apply various culture techniques for the identification of microbes	Apply
C.O. 2: Analyze the various bacteria using gram staining method	Analyze
C.O.3: Identify different anatomical features of angiosperms viz., meristems, roots, leaf, anther and pollen	Remember
C.O. 4: Identify various stages of embryo development in angiosperms	Remember
C.O. 5: Compare various plant tissue culture media and their composition for the development of regeneration protocols	Analyze/Create
C.O. 6: Differentiate various explants and their response in various media composition	Analyze
C.O.7: Design protocols for micropropagation and prepare synthetic seeds of important plants	Create

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1		x				
C.O.2					x	
C.O.3				x		
C.O.4				x		
C.O.5					x	
C.O.6					x	
C.O.7			x			

<u>Microbiology</u>

1. Sterilization technique-chemical, UV and autoclaving.
2. Culture techniques-spread plate/streak plate/ single colony/ stab culture
3. Antibiotic sensitivity assay
4. Cryo-stock preparation-glycerol stock
5. Test for the Coliform bacteria in contaminated water
6. Isolation of Rhizobium from root nodules of leguminous plants.
7. Examination of different types of bacteria
8. Gram staining

Angiosperm (Anatomy /Physiology/Embryology)

1. Study of meristems through permanent slides and photographs.
2. Simple permanent tissue – Parenchyma, Chlorenchyma, Aerenchyma, Collenchyma and Sclerenchyma
3. Primary structure – Dicot stem: *Hydrocotyle,* Monocot stem: Grass
4. Dicot root: *Limnanthemum,* Monocot root: *Colocasia* or any monocot root.
5. Secondary structure – Stem [Normal type]- *Vernonia,* Secondary structure – Root [Normal type] *Ficus* or *Carica papaya*
6. Anomalous secondary thickening – *Boerhaavia*
7. Leaf: Epidermal structures –Stomata. Dicot and Monocot leaf (only Permanent slides).
8. Adaptive anatomy: Xerophyte (*Nerium* leaf); Hydrophyte (*Hydrilla* stem).
9. Structure of anther (young and mature), tapetum (amoeboid and secretory) (Permanent slides).
10. Female gametophyte: *Polygonum* (monosporic) type of Embryo sac Development (Permanent slides/photographs).
11. Pollen germination: in vitro and in vivo viability tests.
12. Study of pollen types using acetolysed and non-acetolysed pollen.
13. Ultrastructure of mature egg apparatus cells through electron micrographs
14. Determination of osmotic potential of plant cell sap by the plasmolytic method.
15. To study the effect of two environmental factors (light and wind) on transpiration by excised twig.
16. Calculation of stomatal index and stomatal frequency of a mesophyte and a xerophyte.

Plant tissue culture

1. Fundamentals and Techniques of Plant Tissue Culture
2. Sterilization methods: physical and chemical
3. Preparation of various tissue culture media: MS and Rooting media
4. Explant preparation, inoculation and initiation of tissue culture
5. Callus formation, Multiplication and Organogenesis
6. Establishment of suspension cultures
7. Micropropagation – Meristem and Nodal culture
8. Preparation of synthetic seeds
9. Protoplast isolation and Culture
10. Hardening and acclimatization in greenhouse

BIO 10606- ANIMAL LAB 2 **(2C= 96 hrs)**

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Identify and Analyze different fossils and differentiate between analogous and homologous structures	Analyze
C.O. 2: Differentiate between various developmental stages of frog and chick embryo development	Analyse
C.O. 3: Identify the life stages of important parasites and differentiate between their life stages	Remember and Analyze
C.O. 4: Compare various lymphoid organs and identify different types of blood cells	Analyse
C.O. 5: Apply the techniques of ELISA and immunoelectrophoresis for the identification of various proteins and peptides	Apply
C.O. 6: Assess the food quality and evaluate various adulterant in fro different types of food	Evaluate
C.O. 7: Identify various storage pests and assess their control options	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1					x	
C.O.2					x	
C.O.3				x	x	
C.O.4					x	
C.O.5		x				
C.O.6						x
C.O.7	x					

<u>Evolution And Developmental Biology</u>

1. Study of fossils from models/pictures.
2. Study of homology and analogy from suitable specimens.
3. Construction of cladograms based on morphological characters.
4. Study of whole mounts and sections of developmental stages of frog through permanent slides: Cleavage stages, blastula, gastrula, neurula, tail-bud stage, tadpole (external and internal gill stages)
5. Study of whole mounts of developmental stages of a chick through permanent slides (Hamburger and Hamilton Stages): Stage 3 (Intermediate Streak)-13 hours, Stage 4 (Definitive Streak)-18 hours, Stage 5 (Head Process)-21 hours, Stage 7-24 hours, Stage 8-28 hours, Stage10-33 hours, Stage 11-40 hours, Stage 13-48 hours, Stage 19- 72 hours and Stage 24-96 hours of incubation

6. Demonstration of the culture of chick embryos from fertilized eggs to study various developmental stages.
7. Study of different sections of the placenta (photomicrographs/ slides).
8. Project report on Drosophila culture/chick embryo development.
9. A visit to Poultry Farm/IVF Centre

Parasitology and Immunology

1. Study of life stages of *Entamoeba histolytica*, *Giardia intestinalis*, *Trypanosoma gambiense, Leishmania donovani* and *Plasmodium vivax* through permanent slides/microphotographs.
2. Study of adult and life stages of *Fasciolopsis buski, Schistosoma haematobium, Taenia solium* and *Hymenolepis nana* through permanent slides/microphotographs.
3. Study of adult and life stages of *Ascaris lumbricoides, Ancylostoma duodenale, Wuchereria bancrofti* and *Trichinella spiralis* through permanent slides/microphotographs.
5. Study of *Pediculus humanus* (Head louse and Body louse), *Xenopsylla cheopis* and *Cimex lectularius* through permanent slides/ photographs.
6. Demonstration of lymphoid organs.
7. Histological study of the spleen, thymus and lymph nodes through slides/photographs.
8. Preparation of stained blood film to study various types of blood cells.
9. Basic patterns of precipitation by Ouchterlony's double immuno-diffusion method.
10. ABO Blood group antigen determination by haemagglutination.
11. Cell counting and viability test from splenocytes of farm-bred animals/cell lines.
12. Demonstration of: (a) ELISA (b) Immunoelectrophoresis
13. Detection of complement activity using haemolysis of antibody-coated SRBC and standard serum

Food, Nutrition and Health

1. To detect adulteration in a) Ghee b) Sugars c) Tea leaves and d) Turmeric
2. Estimation of Lactose in milk and diagnosis of lactose intolerance by measuring hydrogen gas during expiration.
3. Ascorbic acid estimation in food by titrimetry
4. Estimation of Calcium in foods by titrimetry
5. Study of the stored grain pests from slides/photographs (*Sitophilus oryzae*, *Trogoderma granarium, Callosobruchus chinensis* and *Tribolium castaneum*): their identification, habitat and food sources, damage caused and control. Preparation of temporary mounts of the above-stored grain pests.
6. Visit food testing lab /or any agency of food standards
7. Undertake computer-aided diet analysis and nutrition counseling for different age groups. 8. Identify nutrient-rich sources of foods (fruits and vegetables), their seasonal availability and price.
9. Study of nutrition labeling on selected foods

BIO 10607- OPEN END LAB II (2C= 96 hrs)

BIO10608- FOOD, NUTRITION AND HEALTH (2C= 32 hrs)

Course description: The prime focus is to provide the students with a basic understanding of the relationship between food, nutrition and health. It is imperative that focus should be on realistic issues faced by people with respect to nourishment at all stages of life. Unhealthy eating habits particularly the shift from fresh food consumption to packaged foods with added salts and preservatives have contributed to the obesity epidemic in nearly all parts of the world. It is important to understand this link and change eating habits in accordance to one`s age, pregnancy, lactation and physical activity. By taking steps to eat healthy, one can obtain the nutrients required by the body to stay healthy, active, and strong. Apart from physical activity, the intake of the required vitamins, minerals and antioxidants also nourishes the brain. Malnutrition is the main cause of impairment of growth in young children and infants and leads to diseases like Marasmus. Moreover, food hygiene including food and water-borne infections along with food spoilage has also been covered in this course.

Learning Outcome:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1. Explain the association of food and nutrition in promoting healthy living.	Understand
C.O.2. Describe the holistic relationship between nutrition science and health.	Understand
C.O.3. List the nutrition associated disorders or diseases	Remember
C.O. 4. Discuss how neutraceuticals could serve as medicines	Understand
C.O. 5. Explain the importance of nutraceutical science and its application for human welfare	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3				x		
C.O.4	x					
C.O.5	x					

MODULE I **(6 hrs)**

Basic concept of food and nutrition: Food Components and food-nutrients, Concept of a balanced diet, nutrient needs and dietary pattern for various groups- adults, pregnant and nursing mothers, infants, school children, adolescents and elderly. Food Pyramid, Nutritional anthropometry- BMI, waist-to-hip ratio, skin-fold test and bioelectrical impedance; interpretation of these measurements.

MODULE II **(6 hrs)**

Nutritional Biochemistry: Carbohydrates, Lipids, Proteins, their dietary source and role Vitamins- their dietary source and importance Minerals- their biological functions. Dietary

Fibres - Definition, their dietary source and nutritional importance. Elementary idea of Probiotics, Prebiotics, Organic Food.

MODULE III **(8 hrs)**

Health: Definition and concept of health, Major nutritional Deficiency diseases- (kwashiorkor and marasmus), Deficiency disorders, their causes, symptoms, treatment, prevention and government programmes, if any. Lifestyle-related diseases- hypertension, diabetes mellitus, Atherosclerosis and obesity- their causes and prevention through dietary and lifestyle modifications, Social health problems- smoking, alcoholism, drug dependence and Common ailments- cold, cough, and fevers, their causes and treatment.

MODULE IV **(6 hrs)**

Food hygiene: Food and Waterborne infections; Bacterial infection: Cholera, typhoid fever, dysentery; Viral infection: Hepatitis, Poliomyelitis; Protozoan infection: amoebiasis, giardiasis; Parasitic infection: taeniasis and ascariasis their transmission, causative agent, sources of infection, symptoms and prevention; Brief account of food spoilage: Causes of food spoilage and their preventive measures.

MODULE V **(6 hrs)**

Nutraceuticals and Functional foods: Introduction to Nutraceuticals as Science, Properties, structure and functions of various Nutraceuticals: Glucosamine, Octacosanol, Lycopene, Carnitine, Melatonin and Ornithine alpha-ketoglutarate. Use of proanthocyanidins, grape products, flaxseed oil as Nutraceuticals. Nutraceuticals bridging the gap between food and drug, Nutraceuticals in treatment for various disorders. A brief idea about some Nutraceutical rich supplements e.g. Bee pollen, Caffeine, Green tea, Lecithin, etc. Types of inhibitors present in various foods and how they can be inactivated. General idea about the role of Probiotics and Prebiotics as nutraceuticals.

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2. Linda Tapsell. Food, Nutrition and Health. I Edition, Oxford (ISBN: 978-0195518344)
3. Gibney MJ et al. (eds) (2009) Introduction to Human Nutrition. Wiley-Blackwell A John Wiley & Sons Ltd, Nutritional Society.
4. Mann J and Truswell SA, Essentials of Human Nutrition, Oxford University Press
5. Yuan Kun Lee and Seppo Salminen: Handbook of Probiotics and Prebiotics, second ed., John Wiley & Sons, Inc.
6. James Robinson, Deborah J McCornick, Concepts in Health and Wellness, Delmar Cengage Learning, 1st ed
7. Jeremy Hawker, Norman Begg, Iain Blair, Ralf Reintjes, Julius Weinberg, Communicable Disease Control Handbook, 2nd ed
8. Clive de W Blackburn, Food Spoilage Microorganisms, Woodhead Publishing Limited, Cambridge

BIO 10609- PLANT TISSUE CULTURE **(2C= 32 hrs)**

Course description: This course explores the use of biotechnology to both generate genetic variation in plants and to understand how factors at the cellular level contribute to the expression of genotypes and hence to phenotypic variation.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the basic concepts, principles and processes in plant tissue culture	Understand
C.O. 2: List plant hormones, characteristics and their function	Remember
C.O. 3: Employ tissue culture techniques for R&D and for crop improvement and productivity purposes.	Apply
C.O. 4: Discuss the mechanism of agrobacterium mediated gene transfer for plant improvement.	Understand
C.O. 5: Explain the defense mechanisms in plants and the significance of secondary metabolites.	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2			x			
C.O.3		x				
C.O.4	x					
C.O.5	x					

MODULE I **(6 hrs)**

History and Fundamentals of plant tissue culture, laboratory design and sterilization techniques, tissue culture media and preparation, concepts of tissue culture, initiation of plant tissue culture, techniques in plant tissue culture, explant preparation and inoculation, callus formation, multiplication and organogenesis, the establishment of suspension cultures, micropropagation, protoplast culture and fusion, and somatic embryogenesis, the culture of reproductive structures, synthetic seed technology, somaclonal variation.

MODULE II **(6 hrs)**

Plant Growth Hormones and their role in plant tissue culture: discovery, structure, mode of action of the major plant hormones, Plant cell differentiation (Pluripotency and Totipotency).

MODULE III **(7 hrs)**

Application of tissue culture for crop improvement in agriculture, horticulture and forestry, Seed storage proteins, Methods for Plant Conservation, Haploid production, Anther, Pollen, Embryo and ovule culture and their applications, Plant genome organization, Organization and expression of chloroplast genome and mitochondrial genome, Cytoplasmic male sterility., Intergenomic interaction

MODULE IV **(7 hrs)**

Secondary metabolite: Role of Secondary Metabolites in Defense, Communication in insets, plants, animals, Chemical Ecology, Interaction between organism using secondary metabolites. Production of bioactive secondary metabolites by plant tissue culture. Applications of secondary metabolites: Isolation and characterization – drug development, Biopesticides, growth regulators, Biofertilizers. Value addition via biotransformation. Biocatalyst, Bioremediation, Biofuels, Feedstock Chemicals, Designer Chemicals.

MODULE V **(6 hrs)**

Agrobacterium and crown gall tumors: - Ti plasmid & Ri Plasmid vectors. Mechanism of T-DNA transfer to plants, Agro infection. Plant viral vectors. Direct transformation of plants by physical methods. Genetic engineering in plants: -Selectable markers, Reporter genes and Promoters used in plant vectors., Genetic engineering of plants for the production of antibodies, viral antigens and peptide hormones in plants, biodegradable plastics in plants.

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3. Plant tissue culture by Bhojwani. S.S and Razdan. M.K 2004.
4. Plant Propagation by Tissue Culture: Volume 1 & 2. EF George. Exegetics Limited, 1999.
5. Plant cell culture, A Practical Approach, 2nd Edition, Edited by R.A. Dixon and R.A. Gonzales.
6. Natural Products: A Laboratory Guide By Raphael Ikan. Academic Press,1991.
7. Chemistry of Natural Products by Sujata V. Bhat, Bhimsen A. Nagasampagi, Meenakshi Sivakumar. Birkhäuser, 2005.
8. Phytochemical Methods A Guide to Modern Techniques of Plant Analysis By JB Harborne. Springer, 1998.

SEMESTER VII

BIO10701- CELLULAR METABOLISM **(3C= 48 hrs)**

Course Description: This advanced course in biochemistry includes the study of bioenergetics and the metabolism of carbohydrates, amino acids, fatty acids, nucleic acids as well as Electron transport chains. Besides, understanding the regulation of metabolism and the inborn errors of metabolism are also included.

Learning Outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Explain the thermodynamic principles governing biochemical changes.	Understand

C.O. 2: Calculate free energy change, redox potential to assess the thermodynamic feasibility of biological processes	Analyze
C.O. 3: Assess the energetics of catabolic degradation of intermediates in various metabolic pathways.	Evaluate
C.O. 4: Describe the fundamentals of metabolism of carbohydrate, fatty acid amino acid and nucleic acid and their regulation and inborn errors leading to clinical manifestations.	Understand
C.O. 5: Identify and calculate the quantity of biomolecules (carbohydrate, fatty acid amino acid and nucleic acid).	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2				x		
C.O.3						x
C.O.4	x					
C.O.5					x	

MODULE I **(10 hrs)**

Bonds and interactions in Biology; Bioenergetics, High energy compounds, ATP, Oxidation-reduction potential. Carbohydrate Chemistry & metabolism: Overview of Carbohydrate chemistry, biosynthesis, catabolism and their regulation; Glycolysis, Gluconeogenesis, Glycogenesis, Glycogenolysis, Pentose phosphate pathway, Citric acid cycle, Glyoxalate cycle, Overview on glycoconjugates structure and function, Disorders of Carbohydrate metabolism.

MODULE II **(10 hrs)**

Lipid Chemistry & metabolism: Overview on types and functions of lipids. Biosynthesis, catabolism of fatty acids and their regulation; alpha, beta and omega oxidation with emphasis on Beta oxidation, the significance of Ketone bodies and their metabolism. Biosynthesis of different lipids; phospholipids, glycolipids, Cholesterol, Eicosanoids; Inborn errors of lipid metabolism.

MODULE III **(10 hrs)**

Amino acid Chemistry & metabolism: Overview of amino acids and protein, Protein degradation in cells, Amino acid deamination, Urea cycle, metabolic breakdown of individual amino acids, Amino acids biosynthetic precursors and biosynthesis (essential and nonessential amino acids), Nitrogen fixation, inborn errors of amino acid metabolism.

MODULE IV **(10 hrs)**

Nucleic acid Chemistry & metabolism: Overview of nucleic acids and the bases, Biosynthesis (*denovo* and salvage pathways) & catabolism of purines and pyrimidines. Regulation of nucleic acid metabolism; disorders of nucleic acid metabolism, Inhibitors of nucleotide biosynthesis as chemotherapeutic agents.

MODULE V **(10 hrs)**

Photosynthesis and Electron Transport Chain: Biochemical aspects of Reaction centers, Quantum yield. Oxidative phosphorylation: Oxidative phosphorylation–chemiosmotic model, ATP synthase (F_0F_1complex), proton gradient, rotational catalysis, shuttle systems to move reducing equivalents from cytosol to mitochondrial matrix; Regulation of oxidative phosphorylation.

REFERENCES

1. Voet, D. & Voet J. G. Biochemistry (2012). 4th edition, John Wiley and Sons
2. Stryer, Lubertet al., (2015). Biochemistry.8thedition.W.H. Freeman and Co.
3. Lehninger, A. L., Nelson, David L., Cox, Michael M. (2013). Principles of Biochemistry.6th revised edition. Freeman and Co.
4. Devlin, Thomas. M. (2010). Textbook of Biochemistry with Clinical Correlations- 7th edition. John Wiley & Sons.
5. Robert, K., Granner, D. K., & Mayes, P. A. M. (2003). Harper's illustrated biochemistry.
6. Grunwald, P. (2016). Biocatalysis: Biochemical Fundamentals and Applications .2nd reprint Edition. Imperial College Press.
7. Combs Jr, G. F., & McClung, J. P. (2016). The vitamins: fundamental aspects in nutrition and health Academic press.
8. Lurton, R. (2010). Clinical Biochemistry.2nd Edition. Viva books.
9. White, Abraham. (2004).Principles of Biochemistry.6th edition. Tata Mcgraw-Hill.
10. Cooper T.G. (2015). Tools of Biochemistry.2nd edition, Wiley-Interscience
11.Sadasivam S. and Manickam A.(2009). Biochemical Methods, 2ndedn.New Age International Ltd Publishers.
12. Mu, P., & Plummer, D. T. (1988). Introduction to practical biochemistry. Tata McGraw-Hill Education.
13. Jayaraman J.(1992).Laboratory manual in Biochemistry. John Wiley.

BIO10702- CELL BIOLOGY **(3C= 48 hrs)**

Course Description: This course will focus on understanding the structure and function of the cell, which is fundamental to all of the biological sciences. The advanced course in cell biology will focus on both Prokaryotic and Eukaryotic cell biology. The course will help to develop insight into the complexities of cell structure and function and the molecular events that mediate cellular processes, with a specific focus on membrane structure and composition, transport and trafficking; the cytoskeleton and cell movement; and the integration of cells into tissues. In addition, the course will also cover important cellular processes such as cell cycle regulation, signal transduction, metabolic processes, and apoptosis and will attempt to relate defects in these various cellular processes to human diseases.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the fundamentals of cell signaling	Understand
C.O. 2: Describe the structure and function of biological membranes, and analyze cell-cell and cell-matrix interactions and intracellular transport of proteins.	Understand

C.O. 3: Differentiate cellular organelles with the aid of microscopic imaging	Analyze
C.O. 4: Describe how cells grow, divide and die, and how these important processes are regulated.	Understand
C.O. 5: Differentiate different stages in cell cycle based on DNA content	Analyze
C.O.6: Differentiate healthy and dying cells based on morphology, biochemical and molecular basis	Analyze
C.O.7: Analyse a given theoretical problem/case, identify gaps in knowledge and retrieve knowledge independently to be able to present a scientifically sound solution	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3					x	
C.O.4	x					
C.O.5					x	
C.O.6					x	
C.O.7		x				

MODULE I **(10 hrs)**

The Dynamic Architecture and Composition of Cells, Structure and functions of cellular constituents, Membranes and cell architecture, Membrane trafficking, Ion channels and electrical properties of membranes, Transport of ions & small molecules, Protein transport into membranes and organelles, Vesicle trafficking; Vesicle Formation & Cargo Sorting, Vesicle Targeting and Fusion,

MODULE II **(10 hrs)**

Cells in Their Social Context, Microenvironment of the Cell, Cell communication, Cell polarity, Cytoskeleton-Microfilaments, Microtubules, intermediate Filaments, Actin Dynamics, Membrane Channels, receptor mechanisms of action, Cell-Cell Interaction, Cell-Matrix Interactions, Cell Migration and its Control Mechanisms.

MODULE II **(10 hrs)**

Cell Signaling and Signal Transduction: Ligands and surface receptors, GTP binding proteins, cAMP and Calcium signaling, Receptors and associated kinases, RTK signaling and other mechanisms, Major cell-cell signaling pathways—Wnt, TGFβ, Hedgehog (Hh), receptor tyrosine kinase (RTK), nuclear receptor, Jak/STAT, and Notch, Relationships between Signaling Pathways

MODULE IV **(10 hrs)**

Cell cycle, checkpoints, and regulation, Mechanisms of Cell Growth, Survival, Cellular senescence, cell death, Autophagy, Mitophagy, Lysosome-dependent cell death, Apoptosis, necroptosis, Ferroptosis, Pyroptosis, Cellular senescence, cell cycle defects and pathogenesis.

MODULE V **(8 hrs)**

Techniques in cell biology: Advanced Microscopic and flow cytometry techniques, FRET-based assessment of cell signaling, Immune cell sorting and analysis, FISH, Karyotyping, pathological examinations, Western blotting, Determination of calcium flux, localization and translocation of proteins during various cellular events, tracking of cellular events like apoptosis and autophagy, etc, 3D culturing of cells, insect, plant and animal cell isolation and culturing techniques.

REFERENCES

1. Bruce Alberts, Alexander Johnson, Julian Lewis, David Morgan, Martin Raff, Keith Roberts, and Peter Walter, Molecular Biology of the Cell (6th Edition) by Garland Science; 2014
2. Chris A. Kaiser, Kelsey C. Martin, Harvey Lodish, Arnold Berk, Monty Krieger, Anthony Bretscher, Hidde Ploegh, Angelika Amon, Matthew P. Scott Molecular Cell Biology (8th Edition) by, Published by W H. Freeman; 2016
3. Bruce Alberts, Dennis Bray, Karen Hopkin, Alexander D. Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter; Essential Cell Biology (4th Edition) by Garland Science; 2013
4. Gerald Karp, Janet Iwasa, Wallace Marshall; Cell Biology (8th Edition); by Wiley; 2018
5. David E. Sadava; Jones & Bartlett Learning, Cell Biology: Organelle Structure and Function; 1993
6. Harvey Lodish; Arnold Berk; Chris A. Kaiser; Monty Krieger; Anthony Bretscher; Hidde Ploegh; Angelika Amon; Kelsey C. Martin; W.H. Freeman; Molecular Cell Biology (8th Edition), 2016
7. Geoffrey M. Cooper, Robert E. Hausman; The Cell: A Molecular Approach (8th Edition) by Sinauer Associates; 2014
8. Jeff Hardin Gregory Paul Bertoni; Becker's World of the Cell, (9th Edition) by Pearson; 2015
9. Freshney, R. I. Culture of specific cell types. John Wiley & Sons, Inc.; 2005
10. Chris A. Kaiser, Kelsey C. Martin, Harvey Lodish, Arnold Berk, Monty Krieger, Anthony Bretscher, Hidde Ploegh, Angelika Amon, Matthew P. Scott, Molecular Cell Biology (8th Edition) by Published by W. H. Freeman; 2016
11. Julio E. Celis, Cell Biology: A Laboratory Handbook, Volumes 1, 2, 3; Edited by Academic Press, 1994

BIO 10703- ENZYMOLOGY **(3C= 48 hrs)**

Course Description: This course on enzymology covers the classification, naming, isolation and purification of enzymes. It also includes the structure and general properties of enzymes, mechanisms of enzyme catalysis, Enzyme kinetics, different types of enzyme inhibition, regulation of enzymes and applications of enzymes.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**

C.O. 1: Explain principles underlying classification & nomenclature of enzymes and employ suitable methods for isolation and purification of enzymes from different sources.	Understand
C.O. 2: Compare the structure, general properties of enzymes to their mechanism of action.	Analyze
C.O. 3: Analyse the enzyme kinetics to study enzyme characteristics and analyze kinetic parameters to differentiate different types of enzyme inhibition.	Analysis
C.O. 4: Explain and evaluate the role of regulatory enzymes in the regulation of metabolic pathways.	Understand
C.O. 5: Discuss the applications of enzymes in medicine, industry and genetic engineering and also to design synthetic enzymes.	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4	x					
C.O.5	x					

MODULE I **(10 hrs)**

Enzyme nomenclature and classification, the six main classes of enzymes and their subclasses. Extraction and Purification of Enzymes: Extraction of soluble and membrane-bound enzymes; Purification of enzymes; Criteria of enzyme purity; Assay of enzymes; Zymography.

MODULE II **(10 hrs)**

Structure and General properties of enzymes; Enzyme substrate complex; Reaction coordination diagram; Lowering of activation energy; Specificity of enzyme- lock and key hypothesis, induced fit hypothesis and strain or transition state stabilization hypothesis; Mechanism of enzyme catalysis: Acid-base catalysis, covalent catalysis and metal ion catalysis; Factors affecting enzyme activity; Isozymes; Coenzymes; Metalloenzymes; Membrane-bound enzymes; Multienzyme complexes

MODULE III **(10 hrs)**

Kinetics of enzyme catalysed reactions: The relationship between initial velocity and substrate concentration - Michaelis-Menton, Lineweaver–Burk, Eadie-Hofstee and Hanes-Woolf equations and their applications; Pre-steady state kinetics, Fast kinetics to elucidate the intermediates and rate-limiting steps; Enzyme inhibitors.

MODULE IV **(10 hrs)**

Regulatory enzymes and metabolic regulations: Allosteric enzymes, Hill equation. Important metabolic pathways regulated by allosteric enzymes; Regulation of enzymes by covalent modification and zymogen activation. Investigations of active site structure: methods of active site mapping.

MODULE V **(8 hrs)**

Applications of Enzymes: in medicine-diagnostic, in therapeutics, as reagents in clinical chemistry, Enzymes and inborn errors, Industrial applications of enzymes; Applications in genetic engineering/ gene editing. Synthetic Enzyme: Ribozymes, Catalytic antibodies, Enzyme engineering (Protein engineering). Enzyme Immobilization; Immobilization of enzymes and their applications, Kinetics of immobilized enzymes. Biosensors.

REFERENCES

1. Rosevear, A. et al.,(1987). Immobilized enzymes and cells: Adam Higher imprint IOP Publishing.
2. Donald, F. C. (1992). Clinical Chemistry, A fundamental textbook. Saunders Company.
3. Uhlig, H. (2015). Industrial enzymes and their applications. John Wiley & Sons.
4. Palmer, T., & Bonner, P. L. (2007). Enzymes: biochemistry, biotechnology, clinical chemistry. Elsevier.
5. Chaplin, M.F., Burke, C. (1990). Enzyme technology. Cambridge University Press.
6. Grundwald, D. Peter. (2016). Biocatalysis: Biochemical Fundamental and Applications.2nd reprint Edition.
Imperial College Press
7. Grunwald, P. (2009). Biocatalysis: biochemical fundamentals and applications. Imperial College Press.

BIO 10704- MOLECULAR BIOLOGY **(3C= 48 hrs)**

Course description: This course is intended to be an advanced course in molecular biology that builds on the basic undergraduate Molecular Biology course. The course is intended to focus more on the fundamental principles of Molecular Biology than the vast information that is there in the field. At the end of the course, students will be able to explain the principles underlying life at a cellular level. They will also be able to design appropriate experiments to test hypotheses regarding the inner workings of a cell. This course will also introduce students to the latest discoveries in the field by way of analysis of original journal articles and presentations by the students.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Describe the fundamental principles of replication and maintenance and gene expression and regulation in cells	Understand
C.O. 2: Design experimental strategies for testing molecular biological hypothesis	Analyse
C.O. 3: Analyse experimental data to explain the reasons for observed changes in gene expression and activity in cells	Analyse

C.O. 4: Select appropriate model systems for studying different molecular biological processes	Analyse
C.O. 5: Analyse and understand journal articles containing original research	Analyse

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4					x	
C.O.5					x	

MODULE I **(10 hrs)**

Structure of Macromolecules: Bonds and interactions in Biology; Central Dogma; Structure of DNA and RNA; Denaturation & renaturation of DNA, unique and repetitive DNA sequences (LINEs, SINEs), the 3D structure of proteins, protein folding, Dynamics (Hemoglobin, Myoglobin).

MODULE II **(8 hrs)**

Maintenance of Genome: Genome structure, Chromatin and the Nucleosome; Replication of DNA, Extrachromosomal Replicons; Mutability and Repair of DNA, Homologous Recombination; Site-specific recombination, Transposition of DNA

MODULE III **(10 hrs)**

Transcription and Translation of Genetic Information: Mechanism of Transcription; RNA polymerases in eukaryotes, general and specific transcription factors, assembly of pre-initiation complex, enhanceosomes, elongation factors and elongation; Types of introns and mechanism of splicing. Translation; The Genetic Code;

MODULE IV **(10 hrs)**

Promoter analysis and characterization: Deletion mapping, Transient/stable expression system, S1/RNase mapping, EMSA, DNase I Footprinting. RNA editing, catalytic RNA; Regulation of initiation of transcription. Control of gene expression: Transcriptional regulation in prokaryotes; Transcriptional Regulation in Eukaryotes. Post-transcriptional gene silencing, RNA Interference. Post-translational modifications

MODULE V **(10 hrs)**

Regulatory RNAs; Gene Regulation in Development and Evolution; Systems Biology; Model Organisms in Molecular Biology (*Saccharomyces cerevisiae Arabidopsis thaliana*, *Drosophila melanogaster*, *Caenorhabditis elegans*, zebrafish, *Mus musculus*).

REFERENCES

1. Molecular Biology of the Gene,7th edition, Watson et al. 2013, CSHL Press (Primary Reference Book)
2. Genes XII, Lewin et. al., 2017, Jones and Bartlett Pub Inc.
3. Molecular Biology of the Cell, Alberts, Bruce, 6th edition, 2014, Garland Pub. Inc.

4. Biochemistry of Nucleic acids, -Roger L. P. Adams et al.,11th edition, 2007, Chapman & Hall
5. Molecular Cell Biology, Lodish, Baltimore, et al., 8th edition, 2016, W.H.Freeman and Co.
6. Molecular Biology and Biotechnology: A Comprehensive Desk Reference, Meyers, Robert A, 2011 ed. Wiley, New Delhi.
7. Molecular Biology –David Clark and Nanette K Pazdernik, 2nd edition,2013, Academic press
8. Selected research papers to be given

BIO 10705- BIOCHEMISTRY LAB (2C= 96 hrs)

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Evaluate and estimate various biomolecules using standard biochemical techniques	Evaluate
C.O. 2: Analyze the effect of physiological factors such as temperature and pH o the protein folding and structure	Analyse
C.O. 3: Identity carbohydrate (sugars), amino acids/protein, cholesterol and triglycerides and nucleic acids	Remember and Analyze
C.O. 4: Assess the enzyme properties extracted from plant/animals/microbes	Evaluate
C.O. 5: Apply chromatographic and electrophoretic techniques for purification and molecular analysis of the proteins	Apply
C.O. 6: Evaluate the enzyme activity and optimum temperature and pH of the enzymes	Evaluate
C.O. 7: Analyze the importance of enzyme inhibitors in biochemical pathways	Analyze

MAPPING of CO’s and PO’s

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1						x
C.O.2					x	
C.O.3				x	x	
C.O.4						x
C.O.5		x				
C.O.6.						x
C.O.7.					x	

<u>Cellular metabolism</u>

1: Preparation and assessment of the quality of buffers.
2: Estimation of protein concentration by plotting a standard graph of BSA

using a UV spectrophotometer.
3: Estimation of total carbohydrates and free amino acids in cereals.
4: Estimation of protein molecular weight using standard markers and SDS- Polyacrylamide Gel Electrophoresis.
5: Gel Filtration Chromatography.
6: Affinity purification of a recombinant protein and assessment of purity.
7: Identification of proteins using immunoblotting.
8: Determination of the catalytic efficiency of a standard enzyme.
9: A binding assay to quantitate interaction between biological macromolecules.
10. Identification of carbohydrate (sugars), amino acids/protein, cholesterol and triglycerides and nucleic acids
11. Estimation of serum SGOT and SGPT, creatine kinase levels
12. Fluorescence spectroscopy to study the effect of temperature and pH on protein structure.
13. Determination of catalase and cytochrome oxidase enzyme activity of various bacterial strains
14. Other biochemical like citrate utilization, indole, Conversion of lactose to acid, etc using bacterial strains

Enzymology

1. Extraction of an enzyme from an animal/plant/microbial source.
2. Ammonium sulfate/Acetone precipitation of the extracted enzyme.
3. Purification of the enzyme by a suitable chromatographic technique.
4. Determination of molecular weight of the enzyme by SDS PAGE.
5. Progress curve for the enzyme-catalyzed reaction.
6. Assay of the enzyme to determine activity and specific activity
7. Effect of [S] on velocity: Michaelis-Menton Plot and Lineweaver-Burk plot- determination of Km and Vmax.
8. Determination of optimum pH and temperature of the enzyme.
9. Effect of inhibitors on enzyme activity.

BIO 10706- CELL AND MOLECULAR BIOLOGY LAB (2C= 96 hrs)

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1: Define various cell culture methods and their maintenance	Remember
C.O. 2: Analyze various organelles of cells using imaging	Analyse
C.O. 3: Identify various stages of cell cycle using FACS	Remember and Analyze
C.O. 4: Apply the techniques of tissue sectioning and fixation for studying histology	Apply
C.O. 5: Assess the classical Mendelian ratios using Chi-square analysis	Evaluate
C.O. 6: Evalute the enzyme activity and optimum temperature and pH of the enzymes	Evaluate

C.O. 7: Apply Pedigree analysis to study the inheritance of various genetic disorders	Apply
C.O.8: Analyze the nucleic acid using PCR based amplification and blotting techniques	Analyze
C.O.9: Employ molecular biology techniques (restriction digestion and cloning) for nucleic acids	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1				x		
C.O.2					x	
C.O.3				x	x	
C.O.4		x				
C.O.5						x
C.O.6.						x
C.O.7.		x				
C.O.8.					x	
C.O.9.		x				

Cell Biology

1. Cell culture facilities in practice
2. Cell culture in vitro
3. Trypsinisation and methods for detachment of cells
4. Cell counting and reseeding
5. Cell imaging analysis of marker proteins for visualizing; various organelles, proliferation, apoptosis, cell-matrix, differentiation and proteins involved in signal transduction
6. Cell cycle stages by FACS analysis
7. Histology
8. Tissue fixation
9. Tissue sectioning using a cryostat
10. Visualization of the processed tissue samples
11. Immunocytochemistry

Genetics and Molecular Biology

1. Verification of Mendelian ratios using Chi-square analysis/test.
2. Linkage maps based on data from conjugation.
3. Linkage maps based on data from Drosophila crosses.
4. Pedigree analysis- sex-linked disorders, autosomal disorders
5. Study of human karyotype (normal and abnormal)
6. DNA and RNA isolation
7. Primer designing
8. PCR and semi-quantitative RT PCR
9. Analysis of PCR products on an agarose gel.
10. Southern/Northern/Western hybridization techniques
11. Restriction digestion and analysis

12. Competent cell preparation and analysis of efficiency

BIO 10707- GENETICS **(2E= 32 hrs)**

Course description: Genetics is offered as a core course that provides fundamental knowledge of how organisms, populations and species evolve. Apart from Mendel's laws and basic genetics, at the Master's level, this course will provide some of the most incisive analytical approaches that are now being used across the spectrum of biological disciplines.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1: Describe fundamental molecular principles of genetics	Understand
C.O.2: Interpret genetic mapping and analyze crossing data	Analyze
C.O.3: Analyze pedigree charts to come up with predicting genotype and probability of occurrence of particular genotype and phenotype	Analyze
C.O. 4: Explain the inheritance of complex traits	Understand
C.O.5: Analyze banding pattern and its use for analyzing the genetic basis of cancer	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3					x	
C.O.4	x					
C.O.5					x	

MODULE I **(5 hrs)**

Mendel's laws and their chromosomal basis; extension of Mendel's principles: allelic variation and gene function- incomplete dominance and co-dominance, allelic series, testing gene mutations for allelism; gene action- from genotype to phenotype–penetrance and expressivity, gene interaction, epistasis, pleiotropy. Evolution of the concept of the gene, fine structure of a gene (rII locus)

MODULE II **(6 hrs)**

Linkage, Crossing Over and Chromosome Mapping in Eukaryotes: Methods of gene mapping: 3- point test cross in *Drosophila*, Pedigree analysis of Monogenic traits - Autosomal inheritance-dominant, recessive Sex-linked inheritance, Sex-limited and sex-influenced traits, Mitochondrial inheritance, OMIM number, Human genome and mapping.

MODULE III **(6 hrs)**

Complications to the basic pedigree patterns- non-penetrance, variable, expressivity, pleiotropy, late-onset, dominance problems, anticipation, genetic heterogeneity, genomic imprinting and uniparental disomy, spontaneous mutations, mosaicism and chimerism, male lethality, X-inactivation; LOD score for linkage testing, genetic disorders, methods for detection of induced mutations; P- element insertional mutagenesis in *Drosophila*; DNA damage, repair and recombination.

MODULE IV: **(7 hrs)**
Genomes and Genomics, functional genomics and reverse genetics; Complex traits, measuring and analyzing quantitative variation, narrow sense and broad-sense heritability, QTLs and mapping QTLs, Human quantitative traits, Haplotype mapping and GWAS The epigenome, including epigene modifications, such as DNA methylation, histone modification, chromatin remodeling and non-coding RNAs; cellular maintenance of the epigenome; epigenetic control of gene expression, and epigenetics and development. X inactivation and genomic imprinting.

MODULE V **(8 hrs)**
Human genetics- Chromosome banding, karyotype and nomenclature of metaphase chromosome; chromosomal anomalies in malignancy (chronic myeloid leukemia, Burkitt's lymphoma, retinoblastoma and Wilms' tumor); oncogenes and tumor suppressor genes- genetic pathways to cancer.

REFERENCES

1. Introduction to Genetic Analysis, Griffith, AJF, Wessler SR, Carol SB and Dobley J., 11th edition, 2015, W.H. Freeman and Co.
2. Genetics: From Genes to Genomes, Hartwell LH, Goldberg ML, Fischer JA and Hood L., 6th edition, 2018, McGraw Hill.
3. Principles of Genetics, E.J. Gardner and D.P. Snustad, 7th edn, 2015, John Wiley and Sons
4. Genetics, Monroe W. Strickberger 3rd revised edition, 2008, Prentice Hall Pvt. Ltd
5. Essential Genetics- A Genomic Perspective- Daniel L.H, 4th edition, 2005, Jones and Bartlett, USA
6. Principles of Genetics, Robert H. Tamarin, 7th edition, 2007, Tata McGraw-Hill
7. Genetics: a Conceptual Approach, Pierce, B. A., 6th edition, 2016 W.H. Freeman.
8. Evolutionary Genetics, Smith, J. M. 1999, 2nd edition, Oxford University Press.
9. Genetics: Analysis of Genes and Genomics, Hartle, L, 8th edition, 2011, Jones and Barlett, USA
10. Emery's Elements of Medical Genetics, Turnpenny P, and Ellard S, 15th edition, 2017, Elsevier
11. Molecular and Genetic Analysis of Human Traits, Maroni, 2001, Wiley-Blackwell
12. Approaches to Gene Mapping in Complex Human Diseases, Haines and Pericak, 2006, Wiley
13. Selected research papers to be given

BIO 10708- BREEDING AND CULTURE TECHNIQUES **(2E= 32 hrs)**

Course techniques: The course will focus on the commercially important plants, their breeding systems and strategies employed for crop improvement. The paper also covers the aspects of horticulture. Animal breeding and aquaculture are the other important techniques covered under this course.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1: Learn various plant breeding techniques and familiarize with centers for germplasm preservation.	Understand
C.O.2: Appreciate the presence of polyploidy in nature and its application in breeding	Understand
C.O.3: : Describe the importance and use of animal breeding and its industrial application.	Understand
C.O. 4: Design aquaculture set up for fish breeding and use it as a start-up	Create

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4						x
C.O.5						

MODULE I **(7 hrs)**

Plant Breeding: Definition, Objectives. Importance of floral biology in plant breeding, Methods of crop improvement, Sources of germplasm. Centers of genetic diversity, Genetic erosion, Preservation and utilization of germplasm. Gene banks. plant introduction agencies in India- rules and regulations, NBPGR. International exchange of germplasm, Mass selection, pure line selection, clonal selection, Hybridization. Role of interspecific and intergeneric hybridization in crop improvement, Genetics of incompatibility and sterility, Role in crop improvement, Types of male sterility: Methods to overcome incompatibility.

MODULE II **(7 hrs)**

Heterosis breeding, Polyploidy breeding, Induction of autopolyploidy and allopolyploidy, chromosome manipulation, Mutation breeding. Induction of mutations: Physical and chemical mutagens, Resistance breeding, Gene for gene systems of plants. Vertical and Horizontal resistance. Artificial production of epiphytotic conditions and screening procedures for resistance. Molecular markers and their uses- Transgenic plants critical evaluation. Biometrical Techniques in Plant Breeding, Seed production and certification. Centers of crop breeding: International and National (with special reference to Kerala) IPR-Protection of plant variety and Plant breeder's Rights Act. National Biodiversity Policy.

MODULE III **(6 hrs)**

Horticulture: Concept and Scope, Plant growing structures – Greenhouse, Glasshouse and Mist chamber. Plant Propagation: Seed propagation and vegetative propagation- natural and artificial. Artificial methods of vegetative propagation, Cultural practices, Fertilizers: NPK, biofertilizers, green manure, compost, vermicompost. Outdoor horticulture, Types of gardens, Lawns and landscapes. Commercial horticulture, Indoor plants. Arboriculture Bonsai: Principles and procedure.

MODULE IV **(6 hrs)**

Animal Breeding: History and Classification of livestock breeds, Traits and economic importance of different species of livestock, Breeding/ Selection techniques for optimal production, Basis of Selection Sire evaluation, Response to the selection, selection differential and realized heritability, Multi-trait selection, Classification of mating systems, Inbreeding coefficient and coefficient of relationship, Linebreeding, Outbreeding, Outcrossing, Top crossing, Grading up, Criss-crossing, Rotational crossing, In-crossing and In-cross breeding, Species hybridization, Performance records and standardization, Heterosis- Definition, causes, measurement and its application in animal breeding, Breeding methods for improvement of dairy cattle and buffaloes, Conservation of germplasm, Current livestock and poultry breeding programme in the country.

MODULE V **(6 hrs)**

Aquaculture: Aquaculture practices and integrated fish farming, Culture, polyculture, the culture of shrimps, prawns, crabs, edible oysters, pearl oysters and mussels, seaweeds, freshwater fishes, cold water fishes, brackish water fishes. Preparation and maintenance of the aquarium. Preparation and maintenance equipment, water chemistry, aquarium fishes and plants pathology: Major fish diseases - viral, bacterial, fungal, protozoan infections, Control and treatment.

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1. Chopra, V. L. 2012. Plant Breeding Theory & Practice Oxford & Ibh Publishing Co Pvt Ltd
2. Chahal, G. S. & Gosal, S. S. 2002. Principles and Procedures of Plant Breeding. Narosa Publishing House.
3. Singh, B. D. 1996. Plant Breeding: Principles and Methods. Kalyani Publications.
4. Allard, R. W. 1995. Principles of Plant Breeding. John Wiley and Sons, Inc.
5. Sharma, J. R. 1994. Principles and Practices of Plant Breeding. Tata McGraw-Hill Publishers Company Ltd.
6. Hayward, M. D., Bosemark, N.O. & Romagosa, T. 1993 (Eds.) Plant Breeding. Principles and Prospects

SEMESTER VIII

BIO 10801- ADVANCED MICROBIOLOGY **(3C= 48 hrs)**

Course description: The course aims to understand the advanced biology of bacteria, viruses, fungi and associated pathogenesis in plants and animals. The course also helps gain in-depth knowledge of the microflora in various habitats and environmental conditions and their plausible industrial applications.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**

C.O.1: Application of specific molecular markers like 16S rDNA/ 18S rDNA /COXa sequence amplification and analysis for molecular classification of microorganisms	Apply
C.O.2: Construction of phylogenetic tree to understand the relatedness	Create
C.O.3: Construct Antibiogram for analysis of the antibiotic profile of given pathogens-Disk diffusion method	Create
C.O.4: Quantify the antibiotic sensitivity using liquid assay-MIC	Apply
C.O.5: Amplify the R-gene using PCR techniques, confirm its presence by electrophoresis and analyze the sequence data	Apply & Analyze
C.O.6: Isolate and quantitate pure metagenomic DNA from the soil sample.	Apply
C.O.7: Analyze the given metagenomic data set using bioinformatics tools to identify resistome, diversity and function	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1		x				
C.O.2						x
C.O.3						x
C.O.4		x				
C.O.5		x	x			
C.O.6		x				
C.O.7			x			

MODULE I **(10 hrs)**

Bacteriology: Classification, virulence factors, microbial communication system; bacterial quorum sensing;, toxin genes, virulence, Biofilms in disease; Pathogenic bacteria and viruses, AMR genes in pathogenesis, plant diseases, microbial diseases in animals, Human Bacterial diseases-Tuberculosis, leprosy, Cholera, Typhoid, Human microbiota and their role in human health, Drug-resistant bacteria, antibiotics and antimicrobial agents.

MODULE II **(10 hrs)**

Virology: Virus and bacteriophages, Viruses and bacteriophages, general properties of viruses, Viral structure, genetic materials, virulence factors, viral metabolism, reproduction, phages, viral structure, the taxonomy of virus, viral replication, cultivation and identification of viruses; sub-viral particles –viroids and prions. Viruses, bacteriophages and their applications, Viral diseases: Polio, HIV, Hepatitis, Rabies, Influenza, H1N1, SARS, COVID19

MODULE III: **(8 hrs)**

Mycology: Fungal diseases in plants and animals pathobiology, beneficial fungi, Antibiotic production, antibiotic resistance mechanisms and alternative measures.

MODULE IV **(10 hrs)**

Microbial genetics: Organization of the bacterial chromosome, Regulation of gene expression, Induction and repression- the lac operon, regulatory mutants of the lac operon. Quorum sensing and cross-talks. Importance and uses of mutation analysis. Isolation and identification of mutants. Extrachromosomal inheritance. Gene transfer and mapping by conjugation, Gene transfer by transformation and transduction, Transposons. Genetics of bacteriophages- lytic and lysogenic cycles

MODULE V (10 hrs)

Genetic analysis of bacteria: Gene mapping, conjugational analysis, transformation and transduction, Molecular techniques in gene mapping-gene libraries, Restriction mapping and PFGE, Diagnosis and epidemiology-gene probes for detection of pathogens, Detection of virulence genes; diagnostic use of PCR, molecular epidemiology. **Genetic analysis of phages** – complementation and recombination tests with phages. Genetic experiments with the rII genes of phage T4. Deciphering the genetic code using rII mutants. Constructing phage genetic linkage maps using two-factor and three-factor crosses.

Assays to analyze transposition events – suicide vectors and mating out assays. Transposon mutagenesis, cloning genes by transposon mutagenesis, mini-Mu elements and their use in *in vivo* cloning.

REFERENCES:

1. Pelczar, M. J., Chan, E. C. S., & Krieg, N. R. (2001). Textbook of microbiology. MC Graw-Hill publications, 5th edn, New York, 1193, 504-508.
2. Gibson, D. T. (1984). Microbial degradation of organic compounds. Marcel Dekker Inc.
3. Adams, M. R., & Moss, M. O. (2000). The microbiology of food preservation: In Food microbiology.
4. Davis B.D., Dulbecco R., Eisen H N.and Ginsberg H S.(1990). Microbiology.4th edition, J. B. Lippincott Company, Newyork.
5. Frazier, W. C., & Westhoff, D. C. (1988). Food microbiology 4th ed. Tata McGraw-Hill Publishing Co. Ltd. New Delhi.
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7. White, D. (1996). The physiology and biochemistry of prokaryotes: General Pharmacology.
8. Ananthanarayan, R. (2005). Ananthanarayan and Paniker's textbook of microbiology. Orient Blackswan.
9. Pommerville, J. C. (2013). Fundamentals of microbiology. Jones & Bartlett Publishers.
10. Marjorie Kelly Cowan (2015).Microbiology: A Systems Approach,3rd edition, McGraw-Hill Higher Education.
11. Booth S J. (2010)Microbiology: Pearls of Wisdom, 2nd edition, Scientific book center.
12. Sherwood, L., Willey, J. M., &Woolverton, C. (2011). Prescott's Microbiology. McGraw-Hill.
13. Black, J. G. (2005). Microbiology: principles and explorations (Vol. 1). John Wiley & Sons Incorporated.
14. Hogg, S. (2013). Essential Microbiology. John Wiley & Sons.

BIO 10802- PLANT PHYSIOLOGY AND BIOCHEMISTRY (3C= 48hrs)

Course description: The course aims at making students realize how plants function, namely the importance of water, minerals, hormones, and light in plant growth and development; understand transport mechanisms and translocation in the phloem, and appreciate the commercial applications of plant physiology. The course also highlights the importance of secondary metabolites and nitrogen fixation.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1: Describe the importance of physical theories for maintaining the physiology	Understand
C.O.2: Differentiate biodiversity based on morphology, anatomy, cell structure and biochemistry with plant functioning.	Analyze
C.O.3: Explain the significance and transportation of mineral nutrition with respect to plants.	Understand
C.O. 4: Apply the knowledge on plant hormones for crop improvement in plant biotechnology	Apply
C.O. 5: Discuss the process of photosynthesis and the rate-limiting steps	Understand
C.O.6: Apply the knowledge of secondary metabolites and nitrogen fixation in agriculture welfare.	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4		x				
C.O.5	x					
C.O.6						

MODULE I **(10 hrs)**

Physiology: General Introduction on physiological processes, their significance and applications, Water relations of plants, physical aspects of absorption-imbibition, diffusion and osmosis. Water potential and osmotic potential, Plasmolysis and its significance, Mechanism of water absorption-active and passive absorption, root pressure, aquaporins. Pathway of water across root cells, Ascent of sap-vital and physical theories. Transpiration-cuticular, lenticular and stomatal. Mechanism-theories -starch sugar hypothesis, potassium -ion theory. Significance of transpiration, anti-transpirants, Guttation and its significance.

MODULE II **(10 hrs)**

Mineral nutrition: Gross chemical analysis of the plant body, ash analysis, criteria for the essentiality of elements, macro and microelements, the role of essential elements and their deficiency symptoms. Culture methods-sand culture, hydroponics and aeroponics. Mechanism of mineral absorption (a) passive absorption-ion exchange and Donnan equilibrium (b) active absorption -carrier concept, Lundegardh hypothesis, Translocation of solutes: Pathway of movement, phloem transport, mechanism of transport-Munch hypothesis, protoplasmic streaming theory-activated diffusion hypothesis, electro-osmotic theory.

MODULE III **(10 hrs)**

Plant movements: Tropic and nastic movements. Circadian rhythm and biological clock. Stress Physiology: Types of stress- water, temperature, salt, stresses caused by pests and pathogens and pollutants, Plant defense systems and mechanisms. Growth regulators-Auxins, Gibberellins, Cytokinins, Ethylene, Abscisic acid-synthetic plant hormones-practical applications. Senescence and abscission. Photoperiodism. Vernalization, Dormancy.

MODULE IV **(10 hrs)**

Photosynthesis, structure and function of the chloroplast, Fluorescence and phosphorescence, Red drop, Emersion effect; Two pigment systems; Mechanism of photosynthesis-Light reaction, Calvin cycle; comparative study of C3, C4 and CAM plants; photorespiration, Factors affecting photosynthesis-Law of limiting factor, Respiration Energy relation of respiration-RQ and its significance-Factors affecting respiration.

MODULE V **(8 hrs)**

Secondary Metabolites and Nitrogen Fixation: Types, structure, functions, Biosynthesis of Secondary metabolites, economic importance. Plants and Nitrogen: The nitrogen cycle, Nitrogen metabolism: Source of nitrogen, Biological nitrogen fixation-symbiotic and asymbiotic. Nitrogen fixation by blue-green algae-rotation of crops. Genetics of N fixation - Nif genes and Leghaemoglobin. Biosynthesis of amino acids- reductive amination and transamination. GDH and GS/ GOGAT pathway.

REFERENCES

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5. Lehninger A L, 1961. Biochemistry. Lalyan publishers, Ludhiana.
6. Nelson DL, Cox M M, 1993. Principles of Biochemistry. MacMillan Publications.
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8. Plummer D T, 1988. An introduction to practical biochemistry. Tata McGraw-Hill Publishing Company, New Delhi.
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10. Salisbury F B, Ross C W, 1992. Plant Physiology. CBS Publishers and Distributors, Delhi.
11. Srivastava H S, 2005. Plant Physiology. Rastogi publications, Meerut.

12. Verma V, 2007. Textbook of Plant Physiology. Ane Books India, New Delhi.

BIO 10803- HUMAN PHYSIOLOGY AND ENDOCRINOLOGY (3C=48 hrs)

Course description: The students will be introduced to the principles of normal biological function in the human body. Basic human physiology will be outlined and correlated with histological structures. The course also provides students with a basic understanding of human endocrine glands, neuro-endocrine glands and their structure, function and signaling pathways. Students will also study the influence of biological rhythm on hormone secretion.

Learning outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1. Explain the principles of normal biological function in the human body.	Understand
C.O.2. Compare histological structures with their function	Analyze
C.O.3. Discuss how animals maintain an internal homeostatic state in response to changes in their external environment.	Understand
C.O. 4. Describe the endocrine system and the basic properties of hormones.	Understand
C.O. 5. Gain insight into the molecular mechanism of hormone action and its regulation.	Understand
C.O.6. List the endocrine disorders and critically analyze their own and their family`s health issues.	Remember

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3	x					
C.O.4	x					
C.O.5	x					
C.O.6				x		

MODULE I (10 hrs)

Nutritional physiology: Structure and digestive system: General introduction, types of nutrition, mechanical and chemical changes of food in the alimentary canal, balanced diet, nutritional disorders-PEM, vitamin and mineral deficiency, hormonal control of digestion Circulatory physiology: Structure of heart, Blood composition and functions of blood plasma and formed elements, blood groups, mechanism of blood clotting, intrinsic and extrinsic pathways, disorders of blood clotting, anticoagulants, heartbeat, conducting system and pacemaker, pulse and blood pressure, clinical significance, control of cardiac activity, common cardiovascular diseases-arteriosclerosis, atheroslecrosis, myocardial infarction, electrocardiogram, angiogram, angioplasty, Lymph and lymphatic system.

MODULE II **(10 hrs)**

Respiratory physiology: Structure of lungs. Gas exchange, respiratory pigments-structure of haemoglobin, transport of oxygen-Oxyhaemoglobin curve, Bohn effect, transport of CO_2-carbonic acid, carbamino haemoglobin, bicarbonate and chloride shift, carbon monoxide poisoning, bronchitis, asthma, physiological effects of smoking, fibrosis

Renal Physiology: Structure of kidney. Nephron-structure, urine formation, counter current multiplier system, the role of the kidney in osmoregulation, renal disorders-nephritis, haematurea, renal calculi, acidosis, and alkalosis-, fibrosis, Dialysis and kidney transplantation

MODULE III. **(10 hrs)**

Muscle Physiology: Brief account of types of muscles, fast and slow twitch muscles, red and white muscles, the ultrastructure of striated muscle fibre, muscle proteins, simple muscle twitch, summation, tetanus, tonus, ALL or None Law, fatigue, oxygen belt, rigor mortis, physiological and biochemical events in muscle contraction.

Sensory physiology: Structure of eye and ear. Physiology of vision, visual elements and pigments, photochemistry of vision. Eye defects-myopia, hyperopia, presbyopia, astigmatism, cataract. Structure of ear and mechanism of hearing, hearing impairments-deafness, labyrinthine disease. olfactory, gustatory and tactile sense organs.

MODULE IV **(8 hrs)**

Nerve Physiology: Structure of brain, Neurons-structure, types of neuron. Synapse and types of the synapse, nerve impulse propagation, synaptic transmission. Reflex action, refractory period, neurotransmitters, electroencephalogram. Nerve disorders- epilepsy, Alzheimer's disease, Parkinson's disease

MODULE V **(10 hrs)**

Endocrinology: Definition, classification and characteristics of chemical messengers (hormones, neurohormones, neurotransmitters, cytokines, pheromones), Hormone delivery: Endocrine, paracrine and autocrine modes, Hormone feedback mechanisms, Structure and functions of: Pituitary, Thyroid, Parathyroid, Adrenal, Endocrine Pancreas, Testis, Ovary, Endocrine glands in insects, Pars inter cerebralis-corpus cardiacum-corpus allatum complex, Prothoracic glands, endocrine disorders.

REFERENCES

Physiology

1. Best and Taylor. (1990). Physiological basis of Medical Practice. Wilkins Co.
2. Eckert, R. and D. Randell. (1987). Animal Physiology, CBS Publishers and Distributors N. Delhi.
3. Ganong, W.F. (2003), Review of Medical Physiology, McGraw Hill, New Delhi.
4. Guyton, A.C. (1981). Textbook of Medical Physiology, W.B. Saunders Co.
5. Hoar, W.S.(1975). General and Comparative Physiology, Prentice-Hall.
6. Mac. Eleroy, W.D. (1971). Cell Physiology and Biochemistry. Prentice-Hall of India Ltd.
7. Nagabhushanan, R., Kaobarkar M.S. and Sarojini, R. (1983). A textbook of animal physiology, Oxford IBH Publishing Co., New Delhi.
8. Prosser, C.L. (1978). Comparative animal physiology. W.B. Saunders Co.
9. Rama Rao, V., First aid in accidents, Srikrishnan Brothers, Thambuchetty Street, Madras.

10. Schmidt-Nielson K. (2002). Animal Physiology, Prentice Hall India Ltd.
11. Sebastian, M.M. Animal Physiology. Dona Publications, Changanacherry.
12. St. John ambulance associations' textbooks (a) First aid to the injured (b) A preliminary course of first aid to the injured.
13. Subramanyan, S. and Madhavankutty, K. (1977). The textbook of physiology, Orient Longman Ltd., New Delhi.
14. Vander, A.J., Sherman, J.H. and Luciano D.S. (1998), Human Physiology, MacGraw Hill Publishing Co., New Delhi.
15. Withers P.C. (1992). Comparative animal physiology. Saunders College Publishing

Fundamental Endocrinology

1. Hadley: Endocrinology (5th ed. 2000, Prentice-Hall)
2. Turner and Bagnara: General Endocrinology, 6th ed.1984, Saunders)
3. Norris: Vertebrate Endocrinology, Fourth Edition, 2007, Academic Press

BIO 10804- ETHOLOGY AND CHRONOBIOLOGY (3C= 48 hrs)

Course objectives: Ethology is the study of animal behaviour and the wonderful ways in which animals interact with each other, with other living beings, and with the environment in which they live in. The behavioural biology has high applied value and is currently linked to conservation biology, molecular biology, behavioural ecology and integrated pest management. The chronobiology addresses some periodic and cyclic nature of various life phenomena occurring in living beings in nature. They often correlate with external environmental factors. This course aims to provide an overview of animal behaviour and chronobiology starting from a historical perspective to types of behaviours and their evolutionary significance.

Learning Outcomes:

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1. Understand types of animal behaviour and their importance to the organisms.	Understand
C.O.2. Enhance their observation, analysis, interpretation and documentation skills by taking short projects pertaining to Animal behaviour and chronobiology.	Analyze
C.O.3. Relate animal behaviour with other subjects such as Animal biodiversity, Evolutionary biology, Ecology, Conservation biology and Genetic basis of the behaviour.	Apply
C.O. 4. Analyze the various process of chronobiology in their daily life such as jet lag.	Analyze
C.O.5. Describe biological rhythm and its application in pharmacology and modern medicine.	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					

C.O.2					x	
C.O.3		x				
C.O.4					x	
C.O.5	x					

MODULE I **(8 hrs)**
Ethology: Concepts of Ethology, behaviourism and reaction to stimuli, Ethograms, Concepts of Fixed Action Patterns (FAP), Innate Releasing Mechanism (IRM), Action Specific Energy (ASE).

MODULE II **(10 hrs)**
Concepts of Learning and Imprinting, Motivating factors (guppies), Mating systems, Conflict behaviour, Instinctive behaviour & reflex action, the neural basis of sleep and arousal, Learning- Neural basis of learning, memory, cognition, sleep and arousal, Biological clocks, Adaptiveness of behaviour, JP Scott‟s categories of behaviour, External stimulus - circadian rhythms.

MODULE III **(10 hrs)**
Types of orientation-reafference theory of Von Holst & Mittel Steadt., Navigation & migration, Parental care, Development of behavior, Social communication; Social dominance; Use of space and territoriality; domestication and behavioural changes; Social behaviour of termites & Primates.

MODULE IV **(10 hrs)**
Evolution and adaptiveness of behaviour, Altruism, Kin selection, inclusive fitness, selfish gene theory, cultural transmission of behaviour, Hormones and Behaviour, Maternal behaviour- mechanism of hormonal action.

MODULE V **(10 hrs)**
Chronobiology: History, Biological rhythms, Biological clocks, Types, Significance, Measurement, properties, Factors influencing biological rhythms, zeitgebers, Centre and molecular basis of the biological clock, and its’s applications.

REFERENCES

1. Alcock: Animal Behaviour- An Evolutionary Approach. (7th ed.) Sinaur Associates, Inc. 2001.
2. Drickamer & Vessey: Animal Behaviour –Concepts, Processes and Methods (2nd ed.), Wadsworth, 1986.
3. Gadagkar: Survival Strategies-Cooperation and Conflict in Animal Societies. Universities Press,1998.
4. Goodenough et al: Perspectives on Animal Behaviour, Wiley, 1993.
5. Grier: Biology of Animal Behaviour, Mosby, 1984.
6. Halliday and Slater: Animal Behaviour (vols. I-3) Blackwell Scientific Publ., 1983.
7. Krebs & Davis: Behavioural Ecology. (3rd ed.) Blackwell, 1993.
8. Lehner: Hand Book of Ethological Methods. (2nd ed.) Garland, 1996.
9. Manning & Dawkins: An introduction to Animal Behaviour (5th ed.), Cambridge Univ. Press, 1998.
10. Slater & Halliday: Behaviour and Evolution, (1st ed.) Cambridge Univ. Press, 1994.
11. Binkley, S. (1990): The clockwork sparrow: time, clocks, and calendars in biological organisms, Prentice-Hall, New Jersey.

12. Chandrashekaran, M. K. (1985): Biological rhythms, Madras Science Foundation, Chennai.
13. Shapiro, C. M. and Heslegrave, R. J. (1996): Making the shift work, Joli Joco Publications, Inc. Toronto.
14. Nelson, R. J. (2000) An Introduction to Behavioural Endocrinology, 2nd edition, Sunderland Publishers, Massachusetts.

BIO 10805- MICROBIOLOGY LAB (2C=96 hrs)
Learning outcomes

Course Outcome **After the completion of the course, the student will be able to**	**Cognitive Level**
C.O. 1: Apply the basic microbiological techniques for media preparation, sterilization and isolation of bacteria and fungi from various surroundings	Apply
C.O. 2: Employ various biochemical techniques to characterize various microbes	Apply
C.O. 3: Evaluate the bacterial growth kinetics under different stress conditions	Evaluate
C.O. 4: Apply recombinant DNA technology technique to demonstrate the bacterial transformation in *E. coli*	Apply
C.O. 5: Evaluate the protein structures using spectroscopic platforms	Evaluate
C.O. 6: Evaluate the physical and chemical properties of DNA /proteins	Evaluate
C.O. 7**:** To identify the properties of different organic compounds using various spectroscopic techniques	Remember and Analyze

MAPPING OF CO's AND PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1		x				
C.O.2		x				
C.O.3						x
C.O.4		x				
C.O.5						x
C.O.6						x
C.O.7				x	x	

Advanced Microbiology

1. Media preparation, microbial culture (bacterial and fungal).
2. Growth curves, preservation of the bacteria, plating, dilution plating.
3. Effect of temperature, pH, salts and other stress factors on bacterial growth.

4. Isolation of bacteria from various surroundings, Identification of bacteria by biochemical assays and Gram staining.
5. Antibiotic or drug inhibition assays.
6. Transformation and competent cell preparation studying *E. coli* as a model microorganism for R&D.
7. Mammalian virus culture and titration.

<u>Biophysics and Bioinstrumentation</u>

1. Effect of different solvents on UV absorption spectra of proteins.
2. Study of structural changes of proteins at different pH using UV spectrophotometry.
3. Study of structural changes of proteins at different temperatures using UV spectrophotometry.
4. Determination of melting temperature of DNA.
5. Study the effect of temperature on the viscosity of a macromolecule (Protein/DNA).
6. Use of viscometry in the study of ligand binding to DNA/protein.
7. Crystallization of enzyme lysozyme using hanging drop method.
8. Analysis, identification and comparison of various spectra (UV, NMR, MS, IR) of simple organic compounds.

BIO 10806- PLANT AND ANIMAL PHYSIOLOGY LAB (2C= 96 hrs)

Course Outcome **After the completion of the course, the student will be able to**	**Cognitive Level**
C.O. 1: To define the Photosynthetic phosphorylation process in plants	Remember
C.O. 2: Evaluate the total protein content in samples using biochemical techniques	Evaluate
C.O. 3: Evaluate the total chlorophyll and carotenoid content of leaf samples using different solvents	Evaluate
C.O. 4: Apply plant physiology principles to demonstrate osmosis, photosynthesis, transpiration and types of tropism in plants	Apply
C.O. 5: Apply the techniques of tissue sectioning and fixation for studying histology	Apply
C.O. 6: Applying the knowledge of blood typing for blood group identification	Apply
C.O. 7: Evaluating hormones using ELISA based techniques	Evaluate

MAPPING OF CO's AND PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1				x		

C.O.2						x
C.O.3						x
C.O.4		x				
C.O.5		x				
C.O.6		x				
C.O.7						x

Plant Physiology and Biochemistry

1. Experiment to demonstrate root pressure.
2. Extraction and estimation of total proteins by TCA precipitation and Lowry's method.
3. Isolation of chloroplast from fresh leaves and estimation of chlorophyll pigments.
4. Chlorophyll survey of five plants. Quantification, absorption spectra of chlorophyll and carotenoids using different solvents.
5. Hill activity by DCPIP/ ferricyanide reduction.
6. Setting up of Plant Physiology experiments.

    a. Experiment to demonstrate endosmosis and exosmosis (Raisins and fresh grape experiment)
    b. To demonstrate that xylem is the main path of movement of sap in the plant (Ringing experiment)
    c. To demonstrate that oxygen is liberated during photosynthesis (Hydrilla experiment).
    d. To demonstrate the effect of environmental factors on photosynthesis (Warm water, NaCl, KOH, chloroform, etc) using hydrilla experiment.
    e. Experiments to demonstrate the rate of transpiration is equal to the rate of water absorption.
    f. To demonstrate the process of anaerobic respiration.
    g. To study the R. Q. of different respiratory substrates by Ganong's respirometer.
    h. Experiment to demonstrate gravity (Clinostat)

Human Physiology and Endocrinology

1. Preparation of temporary mounts: Neurons and Blood film.
2. Demonstration of haemoglobin using Sahli's haemoglobinometer.
3. Examination of permanent histological sections of mammalian, stomach, lung, kidney, thyroid, pancreas, testis, ovary.
4. Determination of ABO Blood group.
5. Recording of blood pressure using a Sphygmomanometer in resting condition.
6. Study of the permanent slides of all the endocrine glands
7. Estimation of plasma level of any hormone using ELISA
8. Chromatographic separation of steroid hormones using paper chromatography
9. Survey based project on any prevalent endocrine disorder

BIO 10807- RESEARCH METHODOLOGY/BIOETHICS/ BIOSAFETY/ IPR (2E= 32 hrs)

Course Description: This course introduces bioethics, biosafety and the IPR issues related to biotechnological research. It reviews ethical, legal and social issues and practices related to various applications of biotechnology including genetic testing and therapy, cloning, use of stem cells, etc. The practical aspects of performing responsible conduct of research will also be discussed. Discussion topics include biosafety issues regarding rDNA research as well as the various guidelines. The course will also discuss the release of genetically modified organisms to the environment, its impact and safety issues. In addition, the role of IPR and the role of the patent in biotechnology and procedures for patenting and protection of traditional knowledge will be discussed.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1.Understand the ethical, moral, social and legal issues underlying products and processes developed by biotechnology and microbiology	Understand
C.O.2. Analyze and select appropriate biosafety measures for the conduct of experiments using various living organisms	Analyze
C.O.3. Apply the knowledge of Research Methodology to carry out research and document data in a systematic manner.	Apply
C.O. 4. Explain the process of risk assessment analysis of the release of genetically modified organisms	Understand
C.O. 5. Identify potential ethical issues in the conduct of research experiments and to avoid committing unintentional research misconduct	Understand & Apply
C.O.6. Understand the process of applying for a provisional and complete patent through national and PCT mode	Understand
C.O.7.Explain the various measures to protect to biodiversity and traditional knowledge from exploitation by unjust commercial interests	Comprehension

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3		x				
C.O.4	x					
C.O.5	x	x				
C.O.6	x					
C.O.7	x					

MODULE 1 **(6 hrs)**

Research Design, Conduct, Regulation, Recording & Presentation, Formulation of a research problem, Ethics and code of conduct in research, Data falsification, Plagiarism, Data security, Laboratory behavior, Biosafety and IT usage policy, Regulatory issues in Biotechnology, Maintenance of laboratory notebooks, Grant/Fellowship/Report writing, Manuscript Writing, Seminar Presentation.

MODULE II **(6 hrs)**

Literature Search, Use of Databases and Experimental Design, Databases for literature search, Bibliometrics, Citation, Impact factor, Hypothesis as a framework for scientific projects, Experimental design, taking measurements, Data Analysis, sampling, statistical tests with excel, handling data, hypothesis testing

MODULE III **(6 hrs)**

Good Laboratory Practices, Responsibilities of a researcher, handling and storage of biological material, laboratory waste disposal, management of personnel, facilities, buildings and equipment. Biosafety: Safety issues in different fields of Biotechnology, General Guidelines for recombinant DNA (rDNA) research, The Cartagena Protocol on Biosafety; NIH Guidelines; Guidelines for recombinant DNA research in India.

MODULE IV **(6 hrs)**

Classification of microorganisms according to pathogenicity; Containment facilities and Biosafety practices. Risk Analysis and Assessment: Release of GM organisms to the environment- Environmental Impact Assessment and risk analysis. Safety assessment of GMO foods and human clinical trials; GLP and GMP. Plant variety protection, Registration of newer varieties, Rights and obligations: Farmers and breeders rights. Protection of biodiversity, Convention on Biodiversity and the Indian Biodiversity Act, Protection of Traditional Knowledge.

MODULE V **(8 hrs)**

Bio-entrepreneurship and IP management in Biotechnology, Bio-entrepreneurship, Funding options, Introduction to Intellectual Property Rights, Types of IP, Patent search, IP management, Technology transfer therapy and genetic modifications, genetic testing and screening, human clinical trials and drug testing, bio-weapons program/bioterrorism.

REFERENCES

1. Research Methodology: Tools and Techniques Dr. Prabhat Pandey Dr. Meenu Mishra Pandey, 2015

2. Research Methodology-Methods and Techniques, 3rd edition, CR Kothari and Gaurav Garg

3. An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology, Padma Nambisan, 2017, Academic Press.

2. Textbook of Research Ethics - Theory and Practice, Sana Loue, 2002, Kluwer Academic Publishers.

3. Bioethics - An introduction, Marianne Talbot, 2012, Cambridge University Press.

4. Intellectual property rights in agricultural Biotechnology, F. H. Erbisch and K. M. Maredia, 2nd edition, 2003, Cambridge University Press.

5. The Cambridge Textbook of Bioethics, Ed. Peter A. Singer, 2008, Cambridge University Press.

6. Biotechnology, Biosafety and Biodiversity, Sivamiah Shantharam, Jane F. Montgomery, 1999, Oxford & IBH Publ. New Delhi.

7. Genetically modified Food Sources, Safety Assessment and Control, Tutelyal, VA, 1st edition, 2013, AcademicPress.

8. Bioethics: An Introduction to the History Methods and Practice, Jecker Nany S, Johnsen Albert, Perlman, Robert A, 2nd ed., 2010, John & Bartlett, New Delhi.

9. Environmental Safety of Biotech and Conventional IPM Technology, Sharma, HC Dhillon, MK, Sahrawat, KN, 2012, Stadium Press LLC. USA.

10. Bioethics and Biosafety, Sathish MK, 2008, IK International.

11. Intellectual Property Rights, Neeraj Pandey and Khushdeep Dharni, 2014, PHI Learning, Pvt. Ltd.

BIO 10808- BIOPHYSICS AND BIOINSTRUMENTATION (2E= 32 hrs)

Course description: Biological phenomena cannot be understood fully without physical insight. Biophysics is an interdisciplinary frontier of science in which the principles and techniques of physics are applied to understand biological problems at every level, from atoms and molecules to cells, organisms and environment. This paper covers various spectroscopic techniques, hydrodynamic methods, molecular biophysics and introduction to various physical principles responsible for maintaining the basic cellular function and integrity of biological membranes including transport across them.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1. Decribe the basic principles of light and electromagnetic waves and their applications in modern techniques	Understand
C.O.2. Explain the working principle of spectroscopy, CD, NMR, X-ray crystallography etc.	Understand
C.O.3. Calculate the nature of biomolecules using spectrometry	Apply
C.O.4. Explain the forces present in nature and their role in biomolecular interactions	Understand
C.O.5. Discuss the protein folding and the diseases associated with misfolding	Understand
C.O.6. Predict the structure of biomolecules using NMR	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					
C.O.3		x				
C.O.4	x					
C.O.5	x					
C.O.6		x				

MODULE I (6 hrs)

Basic principles of electromagnetic radiation: Energy, wavelength, wavenumbers and frequency, review of the electronic structure of molecules. UV-visible spectrophotometry: Beer-Lambert law, chromophore, structural analyses of DNA/ protein using the absorption of UV light. Fluorescence spectroscopy: Theory of fluorescence, static and dynamic quenching, resonance energy transfer, fluorescent probes in the study of protein and nucleic acids. Mass spectrometry (MALDI-TOF): Physical basis and uses of MS in the analysis of proteins/ nucleic acids.

MODULE II **(6 hrs)**

Optical rotatory dispersion and Circular dichroism: Principle of ORD and CD, analysis of the secondary structure of proteins (denatured and native form) and nucleic acids using the CD. Infra-red spectroscopy: Theory of IR, identification of exchangeable hydrogen, number of hydrogen bonds, tautomeric forms. Magnetic resonance spectroscopy: Basic theory of NMR, chemical shift, medical applications of NMR.

MODULE III **(6 hrs)**

X-ray crystallography and Hydrodynamic methods: Diffraction, Bragg's law and electron density maps (the concept of R-factor and B-factor), growing of crystals (Hanging drop method). Viscosity: Methods of measurement of viscosity, specific and intrinsic viscosity, the relationship between viscosity and molecular weight, measurement of viscoelasticity of DNA. Sedimentation: Physical basis of centrifugation, Svedberg equation, differential and density gradient centrifugation, preparative and analytical ultracentrifugation techniques, fractionation of cellular components using centrifugation with examples.

MODULE IV **(8 hrs)**

Molecular biophysics: Basic thermodynamics: Concept of entropy, enthalpy, free energy change, heat capacity. Forces involved in biomolecular interactions with examples: Configuration versus conformation, Van der Waals interactions, electrostatic interactions, stacking interactions, hydrogen bond and hydrophobic effect. Supercoiling of DNA: Linking number, twist and writhe. Protein folding: Marginal stability of proteins, thermodynamic and kinetic basis of protein folding, protein folding problem (Levinthal's paradox), and role of molecular chaperones in cellular protein folding, basics of molecular and chemical chaperones, protein misfolding and aggregation, diseases associated with protein misfolding

MODULE V **(6 hrs)**

Flow Cytometry and Biological membranes: Basic principle of flow cytometry and cell sorting, detection strategies in flow cytometry. Biological membranes: Colloidal solution, Micelles, reverse micelles, bilayers, liposomes, phase transitions of lipids, transport of solutes and ions, Fick's laws of diffusion, ionophores, transport equation, membrane potential.

REFERENCE

1. Physical Biochemistry: Principles and Applications, 2nd edition (2009), David Sheehan, John Wiley. ISBN-13: 978-0470856031.
2. Physical Biochemistry: Applications to Biochemistry and Molecular Biology, 2nd edition (1982), David Freifelder, W.H. Freeman and Company. ISBN-13: 978-0716714446.
3. Physical Chemistry: Principles and Applications in Biological Sciences, 4th edition (2001), I. Tinoco, K. Sauer, J.C. Wang and J.D. Puglisi, Prentice-Hall, ISBN-13: 978-0130959430.
4. Molecular Biology of the Gene, 7th edition (2007), Watson, J. D., Baker T.A., Bell, S. P., Gann, A., Levine, M., and Losick, R, Benjamin Cummings Publishers, ISBN-13: 978-0805395921.
5. Biophysics, 1st edition (1983), W. Hoppe, W. Lohmann, H. Markl and H. Ziegler, SpringerVerlag, ISBN-13: 978-3540120834.
6. The Physics of Proteins: An Introduction to Biological Physics and Molecular Biophysics, 1st edition (2010), H. Frauenfelder, S.S. Chan and W.S. Chan, Springer, ISBN-13: 978-1441910431.
7. Principles of Instrumental Analysis, 6th edition (2006), D.A. Skooget. al., Saunders College Publishing. ISBN-13: 978-0495012016.

8. Principles of Physical Biochemistry, 2nd edition (2005), K.E. Van Holde, W.C. Jhonson and P. Shing Ho, Prentice Hall Inc. ISBN-13: 978-0130464279.
9. Biophysical Chemistry, 1st edition (1980), C.R. Cantor, P.R. Schimmel, W.H. Freeman and Company. ISBN-13: 9780716711889.
10. Crystallography Made Crystal Clear: Guide for Users of Macromolecular Models, 3rd edition (2010), Gale Rhodes, Academic Press. ISBN: 9780080455549.
11. Introduction to Protein Structure, 2nd edition (1999), C. Branden and J. Tooze, Garland Publishing, ISBN-13: 978-0815323051.

SEMESTER IX

BIO10901- IMMUNOLOGY **(3C= 48 hrs)**

Course Description: This course is intended to provide a solid grounding in immunology, starting with the basic concepts and proceeding to a deeper understanding of the mechanisms of immune functioning. Special emphasis is given to the 'team-work' in immune responses. The course also underscores how the system can go wrong, and how it can be corrected or managed using innovative technology. The recently enhanced appreciation of the pre-eminence of the innate immune system, the importance of the intestinal immune system, and the immunomodulatory potential of the gut microbiota are also highlighted. The course also points out the tremendous scope for basic and applied immunological research.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1. Define/recognize the fundamental organization and associations of the immune system..	Understand
C.O.2. Explain/describe/discuss how the immune system functions in a 'team-work' fashion, and how it is regulated.	Understand
C.O.3. Explain/describe/discuss how the immune system can go wrong, and what types of immuno-pathologies result.	Understand
C.O. 4. Apply appropriate strategies, techniques, and technologies in the management of immune system disorders.	Apply
C.O. 5. Analyze the intricate regulatory mechanisms of the immune system in specific clinical conditions such as hypersensitivities, immunodeficiencies, and autoimmune diseases.	Apply
C.O. 6. Assess the feasibility of adopting or adapting technologies from other disciplines in the correction and/or management of deranged immune systems.	Evaluate

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2	x					

C.O.3	x					
C.O.4		x				
C.O.5		x				
C.O.6						x

MODULE I **(10 hrs)**

Introduction to the Immune System: Historical landmarks, branches, broad divisions of the immune system, antigens vs. immunogens, haptens and carriers, epitopes and paratopes. Hematopoiesis, Theories on immune system functioning; Cells and molecules of the immune system, Inflammation: cellular and molecular events, acute and chronic inflammation, contribution to hypersensitivity and autoimmune reactions; Overview of comparative immunology; Overview of psycho-neuro-endocrine-immunology (PNEI); Overview of the circadian – immune connection; Overview of eco immunology.

MODULE II **(10 hrs)**

Humoral and Cell-mediated immune responses: Structure and functions of primary and secondary lymphoid organs; Development, maturation, and functions of T- and B lymphocytes, molecular markers of T- and B- lymphocytes; structure and functions of antibodies, monoclonal vs. polyclonal antibodies, primary and secondary immune responses, clonal selection and clonal expansion, effector cells of the immune system and their specific roles; Generation of receptor diversity (BCR and TCR), subsets of T- and B- cells; Complement: the 3 pathways, regulatory molecules, disorders of the complement system.

MODULE III: **(10 hrs)**

Strategies of immune functioning: MHC/HLA: its structure, functions, and role in antigen presentation, disorders of antigen processing and presentation, the relative risk associated with specific MHC haplotypes; Lymphocyte trafficking and interaction at the germinal centers, the role of HEV in lymphocyte trafficking; Immune responses against bacteria, fungi, parasites, viruses, and prions; Immune evasion strategies of pathogens.

MODULE IV **(8hrs)**

Clinical immunology: Immunodeficiencies; Hypersensitivity reactions; Autoimmune diseases; Transplantation immunology; Tumor immunology

MODULE V **(10 hrs)**

Immunoprophylaxis and Immunotechnology: Nanotechnology and its applications in immunology; Hybridoma technology and its applications in medicine; Vaccines: their development, and applications in medicine; Immune manipulation of the intestinal immune system, and the gut microbiota Consolidated immunotherapeutic strategies with respect to hypersensitivity, autoimmunity, transplantation, immunodeficiencies, and tumor immunology.

REFERENCES

1. Delves, P.J., Martin S.J., Burton, D.R., and Roitt, I.M., Roitt's Essential Immunology 13th ed. (2017) Wiley Blackwell

2. Murphy K., and Weaver, C., Janeway's Immunobiology 9th ed. 2017 Garland Science

3. J., Stanford, S., Jones, P., and Owen, J.A., Kuby Immunology 8th ed. (2019) PuntMacmillan Education

4. Male, D., Brostoff, J., Roth, D.B., Roitt, I.M. Immunology 8th ed. (2013) Elsevier
5. Mak, T.W., Saunders, M.E., and Jett, B.D., Primer to the Immune Response 2nd ed. (2014) Elsevier Inc.
6. Abbas, A.K., Lichtman, A.H., and Pillai, S., Cellular and Molecular Immunology 1st South Asia ed. (2017) Elsevier
7. Chakravarty, A.K. Immunology and Immunotechnology (2006) Oxford University Press
8. Flaherty, D.K Immunology for Pharmacy (2012)., Elsevier
9. Pathak, S., Palan, U., Immunology Essential and Fundamental 3rd ed. (2011) Capital Publishing Company
10. Chapel, H., Haeney, M., Misbah, S., and Snowden, N. Essentials of Clinical Immunology 6th ed. (2014) Wiley Blackwell
11. Sompayrac, L., How the Immune System Works 5th ed. (2016), Blackwell Wiley
12. Parham, P., The Immune System 4th ed. (2015) Garland Science
13. Bisen P.S., Laboratory Protocols in Applied Life Sciences (2014) CRC Press.
14. A Handbook of Practical and Clinical Immunology Vol. 1. And Vol 2. 2nd ed. (2017) Talwar G.P., and Gupta S.K., CBS Publishers

BIO10902- GENETIC ENGINEERING (3C= 48 hrs)

Course Description: This is an advanced course dealing with the tools and techniques involved in manipulating DNA. The various modules elaborate the different enzymes, the types of vectors used, the expression systems, the heterologous host systems used as well as the various cloning strategies and the processes involved therein. In addition techniques such as PCR, blotting, site-directed mutagenesis, gene transfer and various screening strategies are also included.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1. Elaborate the different enzymes, vectors, as well as cloning strategies	Understand
C.O.2. Apply the different enzymes used in genetic engineering.	Apply
C.O.3. Use different types of vectors for cloning	Apply
C.O. 4. Produce a genomic DNA library and screening for recombinants	Create
C.O. 5. Construct a probe and do blotting techniques	Create
C. O.6. Apply site-directed mutagenesis technique	Create
C.O.7. Employ different types of PCR techniques for gene amplification and clone the amplicon	Apply
C.O.8. Demonstrate heterologous gene expression	Apply
C.O.9. Compare various genome editing tools	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6

C.O.1	x					
C.O.2		x				
C.O.3		x				
C.O.4		x				
C.O.5		x				
C.O.6		x				
C.O.7		x				
C.O.8		x				
C.O.9					x	

MODULE I **(10 hrs)**

Enzymes in rDNA technology: Restriction–modification systems, Deoxyribo nucleases: exonucleases and endonucleases, Restriction enzymes-type-I, II, and III. S1 Nucleases, DNA Ligases, Alkaline phosphatase, DNA polymerase.

MODULE II **(10 hrs)**

Cloning strategies: Shotgun cloning, amplicon cloning, cDNA cloning and its advantages and disadvantages. Construction of genomic DNA and cDNA libraries: Cloning Vectors -plasmids, lambda phage, SV40, Phagemids; Construction of artificial chromosome vectors-BAC & YAC; Expression systems and their applications.

MODULE III **(10 hrs)**

Recombinant DNA-tailing, cohesive ends: Use of linkers, blunt end methods; In vitro packaging, Host vector systems; Probe construction; recombinant selection and screening; Southern hybridization, Colony hybridization, Plaque hybridization.

MODULE IV **(10 hrs)**

Applications: PCR: RT-PCR, Inverse PCR, Nested PCR, LAMP; Molecular Markers - RAPD, RFLP, DNA fingerprinting, microsatellites and minisatellites, SNPs, ESTs, Barcoding; Site-directed mutagenesis; Gene transfer in animals and plants: direct gene transfer and molecular chimeras Microinjection, electroporation, biolistics, direct gene transfer using PEG, calcium chloride, calcium phosphate; Vector mediated gene transfer-Agrobacterium mediated transfer.

MODULE V **(8 hrs)**

Heterologous protein expression in prokaryotes and Eukaryotes- Expression in *E. coli*, yeasts and mammalian cells; Advantages and disadvantages of the various expression systems; cloning of genes into vectors; production and subsequent characterization of the recombinant protein. Genome editing strategies: CRISPR-Cas, TALENS, ZFNs, engineered nucleases, meganucleases; MAGE; Applications

REFERENCES

1. Winnaker, E.L. (2003). From Genes to Clones. India. VCH Panima Educational Book Agency.
2. Karcher, S.J. (1995). Molecular Biology-A Project Approach (1sted.). Academic Press.
3. Primrose, S.B. (2006). Principles of Gene manipulation and Genomics (7thed.). Blackwell Scientific Publications.
4. Lodish, H., Berk, A, et al. (2016). Molecular Cell Biology (8thed.). W.H. Freeman.
5. Watson, J.D. (2007). Molecular Biology of the Gene (6thed.). Pearson.
6. Lewin, B., Goldstein, E.S., et al. (2014). Genes–XI. Jones and Bartlett Publishers.

7. Sambrook, J., Fritsch, E. F., & Maniatis, T. (1989). Molecular cloning: a laboratory manual (No. Ed. 2). Cold spring harbor laboratory press.
8. Ausubel, F. M., Brent, R., Kingston, R. E., Moore, D. D., Seidman, J. G., Smith, J. A., & Struhl, K. (1987). Current protocols in molecular biology New York. NY: Wiley.
9. Freshney, R. I. Culture of animal cells, a manual of basic technique.
10. Kumar, A., Garg, S., Garg N. (2012). Biochemical Test, Principles and Protocols. India: Viva books.
11. Sawhney, S. K., & Singh, R. (Eds.). (2000). Introductory practical biochemistry. Alpha Science Int'l Ltd.
12. Gradwohl, R. B. H., Sonnenwirth, A. C., & Jarett, L. (1980). Gradwohl's clinical laboratory methods and diagnosis. Mosby.

BIO 10903- COMPUTATIONAL BIOLOGY (3C= 48 hrs)

Course description: An interdisciplinary program, this course emphasizes the integration of Computer Science with Biology and introduces the students to various computational methods and software tools for understanding biological databases, gene sequence alignments, gene annotation, protein structure predictions, drug discovery, molecular phylogeny, metagenomics, etc. The broad aim of this course is to make students get basic hands-on training and develop the skill-set required for computational analysis of biological data.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1. Comprehend the amalgamation of computer tools for biological data analysis	Understand
C.O.2. Describe theoretically sources of biological data, and list various biological databases – nucleic acids, protein sequence, metabolic pathways and small molecule environmental issues and evaluate potential solutions	Understand
C.O.3. Identify various file formats of sequence data and tools for submission of data in databases as well as retrieval of gene and protein data from databases	Understand
C.O.4. Discuss the basics of computer languages like Python, Perl and Bio pearl	Understand
C.O.5: Apply the knowledge of languages in analyzing the data retrieved from the databases	Apply
C.O.6. Use the tools for analyzing the phylogeny	Apply
C.O.7. Apply R program and its application for statistical analysis of biological data and Next-generation sequencing	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6

C.O.1	x					
C.O.2	x					
C.O.3	x					
C.O.4	x					
C.O.5		x				
C.O.6		x				
C.O.7		x				

MODULE I **(10 hrs)**

Basic algorithms in Computational Biology, Introduction to sequence alignment (only general ideas, not algorithm) - Local and global, pairwise and multiple, BLAST. Web programming and Databases, Introduction to Bioinformatics-Drug discovery, protein structure elucidation, molecular dynamic simulation, and genomic data analysis.

MODULE II **(8 hrs)**

Python Programming basics and biological application-next gen sequencing and big data management: Introduction to Python, Language Components: Functions Classes in Python, String Processing

MODULE III **(10 hrs)**

Perl and Bioperl programming and applications: Perl Basics: Evolution & Environment – Features of Perl; Scalar Data & Operators, Control Structures. Lists & Arrays, Array Functions, Associate Arrays, Arrays & Data Containers, Hash. Functions: User-defined functions – Built-in Functions, References, Regular Expressions – Processing Text with R.Es. Strings & Sorting Smart Matching, Perl Modules

MODULE IV **(10 hrs)**

Computational genomics, proteomics and CADD phylogenetics; To introduce basic genomic and transcriptomic sequence processing algorithms and concepts and impart skills regarding the use of popular software tools in this area. String view of DNA: Basic file formats: FASTA, GenBank, EMBL, GCG, PIR, Phylip, Nexus file formats etc. Sequence Data Bases, detailed study of GenBank of NCBI- typical Gen Bank (DDBJ+EMBL) for DNA and RNA, Sequence Representation & Analysis, Sequence alignment

MODULE V **(10 hrs)**

R programming, neural networks, machine learning and artificial intelligence; Introduction: R environment; Why R? R for Computational Biology and Bioinformatics; Installing R; R- GUI and IDE; Running R. Programming with R: R as a deluxe calculator, Objects: creating objects and assigning values, Types of objects: vector, matrix, array, factor, list, data frames and functions; Data structures, Control Statements in R, Graphics in R, statistics in R

REFERENCES

1. Ghosh, Z. and Mallick, B. (2008). Bioinformatics: Principles and Applications. Oxford University Press.
2. Lesk M. Arthur (2014). Introduction to Bioinformatics. Oxford University Press.
3. Pevsner, J. (2009). Bioinformatics and Functional Genomics. II Edition, Wiley Blackwell.
4. Attwood Teressa K. and David Parry- Smith (2007). Introduction to Bioinformatics. Pearson Education.

5. Mount, D. W. (2005). Bioinformatics: Sequence and Genome Analysis. CBS Publishers and Distributors Pvt. Ltd., Delhi.
6. Barry, P. (2010). Head First Python. "O'Reilly Media, Inc.".
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8. Mark, S. (2009). Programming in Python 3. Pearson Education India.
9. Lutz, M. (2013). Learning python. "O'Reilly Media, Inc.".
10. Turnquist, G. L. (2011). Python Testing Cookbook. Packt Publishing Ltd.
11. Arbuckle, D. (2010). Python Testing: Beginner's Guide. Packt Publishing Ltd.
12. Wentworth, P., Elkner, J., Downey, A. B., Meyers, C., & List, C. (2011). How to think like a computer scientist.
13. Adler, J. (2010). R in a nutshell: A desktop quick reference. "O'Reilly Media, Inc.".
14. Gentleman, R. (2008). R programming for bioinformatics. CRC Press.
15. R, Notes on R: A Programming Environment for Data Analysis and Graphics Version 2.10.1.

BIO 10904- ENVIRONMENTAL BIOLOGY (3C= 48 hrs)

Course description: The primary aim of the syllabus is to sensitize the students about the paramount role and importance of nature. This course provides an introduction to the principles of environmental biology, ecology, and the relationship between humans and the natural world. This course will provide students with a broad survey of environmental science with an emphasis on scientific literacy, current events, global and international issues, and historic context. Biodiversity, conservation and biogeography are the other aspects of this course that will be addressed.

Learning outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1. Comprehend the interactions and energy flow concepts integral to environmental science	Understand
C.O. 2. Analyze current environmental issues and evaluate potential solutions	Analyze
C.O. 3: Relate the features of human populations to different types of environmental degradation	Understand
C.O. 4: Assess the costs/benefits of conservation vs. remediation or technological solutions.	Analyze
C.O. 5: Recognize the impact of globalization on the environment	Understand

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2		x				
C.O.3	x					
C.O.4		x				
C.O.5	x					

MODULE I **(10 hrs)**

Ecology: Biotic and abiotic factors and their interactions, structure, basic components, their interactions and inter-relations, Fundamental concepts relating to the energy-first and second law of thermodynamics, entropy. Gaseous and sedimentary cycles. Characteristics of the population: density, natality, mortality, biotic potential environmental resistance, growth forms, immigration, emigration and migration, Characteristics: species diversity, stratification, dominance, boundaries, ecotone and edge effect, ecological indicators, Ecological Energetics, Energy flow, primary and secondary productivity, standing crop, Food chain, food webs, trophic levels and ecological pyramids, Classification of ecosystems based on energy input.

MODULE II **(10 hrs)**

Transition and stability in communities, Succession-types, Trends, and Stages, Relevance of ecosystem development theory to human ecology, prospects for detritus agriculture, the compartment model, Species Interactions: Intra and interspecific interactions, Types of interspecific interactions, and coevolution.

MODULE III **(11 hrs)**

Biodiversity: Introduction, definition, levels of biodiversity (genetic diversity, species diversity and ecosystem diversity), values of biodiversity, Diversity indices: Alpha diversity, Beta diversity and gamma diversity; the species diversity and ecosystem stability, Biodiversity in India: Major biogeographic zones of India, hot spot biodiversity -characteristics; an outline of the features and biodiversity of hot spots in India (the Western Ghats and Himalaya), Features, structure and biodiversity of some of the Indian ecosystems; Terrestrial ecosystems (forest, grassland, desert), aquatic ecosystems, freshwater, marine estuarine

MODULE IV **(10 hrs)**

Conservation Biology-Depletion of biodiversity: Current estimates of species loss, causes of biodiversity loss, impacts of biodiversity loss, Strategic species concepts; keystone species, indicator species and umbrella/Flagship species. Strategies of conservation: in situ and ex situ conservation, gene banks, the establishment of protected areas, habitat conservation captive public awareness and other relevant measures.

1. An evaluation of the “Project Tiger’ and “Project Elephant’ programmes
2. World conservation strategy (1980)
3. National biodiversity action plan 2008: a brief outline of objectives and plans
4. International conventions and treaties for the conservation of biodiversity: Stockholm declaration on the human environment (1972), Convention on Regulation of Antarctic Marine Resources activities (RAMRA, 1986), World Charter for Nature (1982), Kyoto Protocol and Brundtland: framework Convention on Climate Change (UNFCCC) report 1987
5. Earth summit (1992)-detailed study-Ratio Declaration on environment and development, Agendas 21, Forest principles, Convention on Biological diversity
6. Species based treaties: Migratory bird treaty act (MBTA) OF 1918, INTERNATIONAL CONVENTION for the Regulation of Whaling (ICRW), Washington, 1946, Convention for the conservation of Antarctic seals,1972, Convention on International Trade on Endangered species 1975
7. Ecosystem-based treaty: Ramsar convention, 1981-Ramsar sites in India and Kerala

MODULE V **(8 hrs)**

Biogeography: Major terrestrial biomes, Savanna Biogeographical zones of India, Applied Ecology, Carbon credit, Carbon trading, Blue Carbon, Green building technology and its ecological importance. Interlinking of major rivers of India, Sethusamudram ship canal project. Biodiversity with special reference to India-status, monitoring and documentation, major drivers of biodiversity change, Major approaches to management, Indian case studies on conservation & management strategy (concepts of project tiger, Biosphere reserves). Phytogeography- concept & definition. Vegetation in India Phytogeographical regions of India

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8. David Quammen. 1997. The Song of the Dodo: Island Biogeography in an age of Extinctions. Scribner. ISBN 0-684-82712-3
9. Dick Neal- Introduction to population Biology- Cambridge University Press
10. Eugene P.Odum- Fundamentals of Ecology- W.B.Saunders Company.
11. Fred, Van Dyke (2003). Conservation biology-foundation concepts, applications-Mc McGraw-Hill, New Delhi.
12. MacArthur, R. H. and Wilson, E. O.(1967). The Theory of Island Biogeography. Princeton, N.J.: Princeton University Press.
13. Magurran, A. E.(2004). Measuring biological diversity. Oxford: Blackwell Publishing. ISBN 0- 632-05633-9
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15. Peter.S.(2002). Ecology- Theories and Applications. Prentice-Hall of India.
16. Whittaker, Robert H. Communities and Ecosystems New York: MacMillan Publishing Company, Inc., 1975.

BIO 10905- IMMUNOLOGY LAB (2C= 96 hrs)

Learning outcomes

Course Outcome **After the completion of the course, the student will be able to**	**Cognitive Level**
C.O. 1: Evaluating the blood cell indices using a haemocytometer	Evaluate
C.O. 2: To define the basic principles of heaemagglutination and immunodiffusion	Remember
C.O. 3: To evaluate antibodies or complement proteins attached to blood cells using diagnostic techniques	Evaluate

C.O. 4: To define the basic principles of immunoelectrophoresis	Remember
C.O. 5: To apply knowledge of molecular biology and immunogenetics to detect specific proteins using western blotting techniques	Apply
C.O. 6: To evaluate and quantifying peptides, proteins, antibodies and hormones using the ELISA technique	Evaluate
C.O. 7: Evaluating the variations in the immune system	Evaluate

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1						x
C.O.2				x		
C.O.3						x
C.O.4				x		
C.O.5		x				
C.O.6						x
C.O.7						x

1. Differential white cell count
2. Haemagglutination (Direct and Indirect)
3. Immunodiffusion (Ouchterlony, Mancini)
4. Complement fixation test
5. Coombs' test
6. Basic immunoelectrophoresis
7. Rocket immunoelectrophoresis
8. Western blotting
9. ELISA
10. HLA typing (immunological and PCR-based)

BIO 10906- GENETIC ENGINEERING AND COMPUTATIONAL BIOLOGY LAB (2C= 96 hrs)

<u>Genetic Engineering</u>

Learning outcomes

Course Outcome **After the completion of the course, the student will be able to**	**Cognitive Level**
C.O. 1: To apply basic principles of molecular biology to isolate DNA from different tissue samples	Apply

C.O. 2: To apply molecular biology and recombinant DNA technology to study transformation and plasmid DNA isolation	Apply
C.O. 3: Apply Recombinant DNA technology to demonstrate restriction and ligation of DNA	Evaluate
C.O. 4: Apply techniques of molecular biology for extracting RNA and cDNA from leaf samples	Apply
C.O. 5: Apply Polymerase chain reaction techniques to demonstrate the various type of PCR techniques	Apply
C.O. 6: Evaluate the expression kinetics of various genes using Quantitative PCR	Evaluate
C.O. 7: To define various sequencing platforms of DNA	Remember

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1		x				
C.O.2		x				
C.O.3						x
C.O.4		x				
C.O.5		x				
C.O.6						x
C.O.7				x		

1. Isolation of genomic DNA (Bacteria, bacteriophage, plant and rat liver) and isolation of metagenomic DNA
2. Isolation of plasmid DNA from transformed E.coli
3. Restriction digestion and analysis of DNA
4. Isolation of total RNA and cDNA library construction(Demo)
5. Preparation of competent cells and Transformation in E.coli
6. Construction of genomic DNA library
7. PCR Techniques – BOX, ERIC, Nested
8. Real-time PCR (demonstration)
9. LAMP (demonstration)
10. DNA sequencing (demo by industrial visit)

<u>Computational Biology</u>

1. Facilitating access from various Bioinformatics databases: NCBI, PDB, SWISS PROT, Pfam, etc., and pairwise sequence alignment using BLAST.
2. Database creation and management using PHP-MySQL,
3. Writing programs using python features including functions, string handling as well as object-oriented features,
4. Data analysis using the R statistical software
5. Data analysis using Perl programming language
6. Validating DNA/ RNA/ Amino acid sequences,

7. Finding complement & reverse complement of DNA sequence,
8. Writing a sequence in Fasta format,
9. Computing the nucleotide composition of a given DNA sequence.
10. Computing the amino acid composition of a given protein sequence. : Finding the AT Composition of a given DNA sequence, Finding the GC Composition of a given DNA sequence, Finding the ORFs in a given DNA sequence, Transcribe a DNA sequence into RNA.
11. PERL: Translate the given DNA sequence into the corresponding amino acid sequence
12. Mapping amino acid sequence with different physiochemical features like hydrophobicity, finding n-mer frequencies in DNA and amino acid sequence

Molecular Taxonomy

I. Familiarising with molecular marker-based techniques,

1. RFLP
2. RAPD,
3. AFLP,
4. SSR
5. ISSR
6. SCAR
7. SNPs

II. Prediction of the evolutionary link and phylogenic relationship of plants and animals from their genomic data
III. Study the biogeographic distribution of flora and fauna in Kerala, India via molecular taxonomy

Genomics and Proteomics

1. Find the secondary and tertiary structure of the given protein sequence.
2. Design primer for mitochondrial COX1 gene
3. Analyze the metagenomics data of soil microbiome for resistome, diversity and function
4. Analyze the transcriptomics data of soil for expression of resistance components
5. Design drugs for a given cancer marker as a receptor
6. Docking of the given ligand on the receptor and find the interactions

BIO 10907- GENOMICS AND PROTEOMICS (2E= 32 hrs)

Course description: In this course, we use the genomics approach to understand the proteome, predict protein structure from DNA sequence data, understand protein-protein interactions, and use of different tools for the analysis of genomic data sets. Besides, this course also includes the methods for gene annotation to gene prediction.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1 Understand Protein sequencing, Nucleic acid sequencing and their analysis.	Understand
C.O. 2 Analyze Gene expression and establish the genomic library	Analyze
C.O. 3: Design primer for a specific marker gene	Apply

C.O. 4: Describe proteins interaction, activity, modification and function	Understand
C.O. 5: Apply Protein modeling and molecular dynamics methods to study structure from sequence	Apply
C.O.6: Discuss the Design drugs from data of functional genomics and proteomics	Understand
C.O.7: Analyze the metagenomics data of soil microbiome for resistome, diversity and function	Analyze
C.O.8: Analyze the transcriptomics data of soil for expression of resistance components	Analyze

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2					x	
C.O.3		x				
C.O.4	x					
C.O.5		x				
C.O.6	x					
C.O.7					x	
C.O.8					x	

MODULE I **(6 hrs)**

Visualization and protein structure prediction: Protein structure prediction for known folds and unknown folds (secondary structure prediction, prediction of transmembrane regions, homology modeling); Online modeling servers (e.g.-SWISSMOD), Molecular visualization software-Kinemages and chemscape, Chime molecular visualization, Rasmol, pymol, Discovery Studio.

MODULE II **(6 hrs)**

Structural proteomics: Methods of sequence-based protein prediction. Definition of protein families – protein families and classification, SCOP and CATH, patterns, profiles, sequence vs family comparison. Homology modeling, prediction of protein structure from sequences, functional sites, FSSP, 3Dee

MODULE III **(6 hrs)**

Protein folding: Protein folding problem, protein folding classes, protein identification and characterization:- AACompIdent, TagIdent, PepIdent and MultiIdent, PROSEARCH, PepSea, PepMAPPER, FindPept, Predicting transmembrane helices.

MODULE IV **(8 hrs)**

Tools and methods in genomics: Stand-alone packages for sequence alignment- Bioedit, MEGA, Submitting, DNA sequence in Genbank - bankIt, Sequin, tbl2asn, Primer designing, Tools for primer designing. Gene ontology and annotation; Prediction of genes and protein-coding regions, Conserved sequence pattern discovery; Tools for gene prediction; Whole-genome analysis; Gene mapping; Genome sequencing strategies, Next Generation Sequencing platforms, Transcriptome sequencing- *de novo* and resequencing, Metagenomics - MG-RAST.

MODULE V **(6 hrs)**

Drug designing: Introduction, Structure-based drug designing approaches Target Identification and Validation, receptor mapping, active site analysis and pharmacophore mapping, Grid maps. Introduction to docking methods to generate new structure; Tools and Molecular docking programs: AutoDock, Dock, HEX, Cheminformatics.

REFERENCES

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2. Xiong, J. (2006). Essential bioinformatics. Cambridge University Press.
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analysis—a Bioinformatics perspective. Briefings in bioinformatics, 13(6), 728-74

BIO 10908- MOLECULAR TAXONOMY **(2E= 32 hrs)**

Course Description: This course aims to provide an understanding of taxonomy at the molecular level. The course in deeper insight into the taxonomical concept, aids and tools for classification, nomenclature, characterization of biodiversity. In addition, it will provide the current trends of systematic tools based on a computer algorithm and molecular markers.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O. 1 Understand the advanced level of systematics concepts and tools	Understand
C.O. 2 Identifying the taxonomical position of living forms based on the advanced taxonomical tools.	Apply
C.O. 3: Differentiate and classify various life forms in the basis of their molecular architecture.	Analyze
C.O. 4: Employ computer-aided algorithms for profiling of genomic data for taxonomical purpose.	Apply

MAPPING of CO's and PO's

	Programme Outcomes					
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2		x				
C.O.3	x					
C.O.4		x				
C.O.5	x					

MODULE I **(6 hrs)**

Introduction: Definition and basic concepts in Systematics and Taxonomy, Levels of Taxonomy: Alpha, Beta and Gamma taxonomy, Importance and applications of taxonomy, Goals of taxonomy, Definition of systematics, Definition of classification, Species: Monotypic species, Polytypic species, Ecospecies and Cenospecies, Morphospecies, Super species, Species as a Population Complex, Species Concepts: Typological Species Concept, Nominalistic Species Concept, Biological Species Concept, Evolutionary Species Concept, Difficulties in the application of the biological species concept

MODULE II **(6 hrs)**

Classification: Classification, Purpose of Classification, Theories of Classification: (a) Essentialism (b) Nominalism (c) Empiricism (d) Cladism (e) Evolutionary Classification Hierarchy of Categories: The objectives of classification, Taxonomic Collections and the Process of identification, Taxonomic collections: Types of collections, Value of Collection, Purpose of scientific collection, Preservation of Specimens, Labeling; Curating of collections, Curating of types, Identification- Methods of identification, Use of keys, types of keys, Merits and demerits of different keys, Description and publication

MODULE III **(7 hrs)**

Taxonomic Characters: Nature of taxonomic characters, Taxonomic characters and adaptation, Kinds of taxonomic characters (a) Morphological (b) Physiological (c) Ecological (d) Ethological and (e) Geographical Characters, Taxonomic characters and classification, Taxonomic characters and evolution, Functions of taxonomic characters, Zoological Nomenclature, Brief History of nomenclature, International Code of Zoological Nomenclature, The nature of scientific names, Species and infraspecies names, Gender of generic names, Synonyms and Homonyms, The Law of Priority, Rejection of names: Type method and different kinds of types

MODULE IV **(6 hrs)**

Newer trends in systematics: Chemotaxonomy and serotaxonomy, Cytotaxonomy, Numerical taxonomy, Cladistics, Molecular Taxonomy, Molecular Phylogenetics, phylogenetic trees, molecular markers (allozyme markers, microsatellite, arbitrary nuclear markers, and neutral markers), Advantages of molecular data, DNA Barcoding, sine differential OCR, Multiplex PCR, RFLP, AFLP, RAPD, Quantitative PCR, LAMP.

MODULE V **(7 hrs)**

Regulations in Taxonomy: Ethics related to taxonomic publications, Authorship of taxonomic papers, Correspondence, Suppression of data, Undesirable features of taxonomic papers, Taxonomist and user communities, Taxonomic impediments, Impediments in taxonomic collections and maintenance, Shortage of manpower, lack of funding for taxonomic research, Lack of training and library facilities, Impediments in publishing taxonomic work, Solutions to overcome the impediments, Improve international co-operation (b) Development of taxonomic centers.

REFERENCES

1. Alfred J.R.B and Ramakrishna.2004. Collection, Preservation and Identification of Animals. Zoological Survey of India Publications.
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SEMESTER X

BIO 11001 INNOVATION AND ENTREPRENEURSHIP FOR BIOLOGISTS (2E=32 hrs)

Course Description: The objective of this course is to expose the students to the field of innovation and entrepreneurship with a specific focus on life science. Student will also be familiarized with the process of developing a life science enterprise. In this course you will learn the tools and trades of becoming an entrepreneur. Course will teach you the various aspects of entrepreneurship; from the fundamentals of selecting an idea and developing a product or process; Preparing a business plan to Identifying and securing investors; setting up a company to meeting the regulatory requirements. Student teams will perform various activities of entrepreneurship: from identifying a market need after market survey and coming up with a solution to making a business plan and pitching to investors.

This course is conducted jointly by Department of Biotechnology and School of Management Studies at CUSAT and outside resource persons experienced in life science entrepreneurships and soft-skill training who will be invited for discussion/workshops. This course will be conducted in workshop mode. Case studies will be included with active participation. The practical component will include case studies, discussions, brainstorming, presentations, etc.

Learning Outcomes

Course Outcome After the completion of the course, the student will be able to	**Cognitive Level**
C.O.1: . Describe the various programmes and opportunities for entrepreneurship in life science in India	Understand
C.O.2: Apply innovation tools such as ideation and design thinking for generating innovative ideas	Apply
C.O.3: Analyse real time data to explore and establish relationships in the areas of entrepreneurship decisions	Analyze
C.O.4: Identify potential funding sources and how to sell the idea for successful funding	Apply

C.O.5: Evaluate various business ideas in the field of life science and select the most appropriate one on the basis of opportunity identification, opportunity evaluation and feasibility studies	Evaluate
C.O.6: Generate new bio-entrepreneurship ideas and create business plans and proposals for starting business or business expansion/diversification.	Create

MAPPING of CO's and PO's

Programme Outcomes						
Course Outcomes	P.O.1	P.O.2	P.O.3	P.O.4	P.O.5	P.O.6
C.O.1	x					
C.O.2		x				
C.O.3					x	
C.O.4		x				
C.O.5						x
C.O.6			x			

MODULE I **(6 hrs)**

Innovation and entrepreneurship: Invention-innovation differences; Types of innovation; creativity; innovation ecosystem; challenges of innovation management; steps in innovation management; technology and innovation- new business models. State and scope of life science innovations and entrepreneurship in India and the world; unique opportunities and challenges of Bio-entrepreneurship.

MODULE II **(6 hrs)**

Entrepreneurship: Definition, traits, characteristics, qualities and functions of entrepreneurs; Entrepreneurial Behaviours and entrepreneurial motivation; Entrepreneurship Theories; Entrepreneurship types: Social entrepreneurship and Technology entrepreneurship, Family business; Start-up landscape and innovation hubs; Innovation in Indian context.

MODULE III **(6 hrs)**

Entrepreneurship: Role in economic development. Entrepreneurial climate in India; Ease of doing business, Government support for entrepreneurship, Start-up India Programme, Pradhan Mantri Mudra Yojana, Assistances for Biotech enterprises, BIRAC/BIG, Business Incubation and other schemes. MSME Policy: various schemes and support.

MODULE IV **6 hrs)**

Idea generation: Design thinking, customer journey mapping, Idea evaluation; lean start-up; Business plan: elements-technical-marketing-financial, preparation of Business plans.
Sources of Finance: Venture capital, angel investment, crowd funding. Mechanics of setting of new enterprises – forms of business organization.

MODULE V **(8 hrs)**

Protection of Intellectual Property Rights, Patent, Trademark and Copyrights. Managerial problems of new enterprises; production purchasing, financing labour and marketing problems.

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BIO 11002- Project DISSERTATION (16C)