ATMANIRBHAR BHARAT
SWAYAMPURNA GOA

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(Accredited by NAAC)

GU/Acad –PG/BoS -NEP/2024/663 Date: 21.11.2024

Ref: GU/Acad –PG/BoS -NEP/2024/95 dated 15.05.2024

CIRCULAR

In supersession to the above referred Circular, the approved Syllabus of the **Bachelor of Science in Chemistry** Programme with following changes is attached.

- Number of Credits for Course CHC-211 "Basic Industrial Chemistry" shall be 3T+1P instead of 4T.

The Dean/ Vice-Deans of the School of Chemical Sciences and Principals of the Affiliated Colleges offering the **Bachelor of Science in Chemistry** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2024.11.21 13:11:50 +05'30'

(Ashwin V. Lawande)
Deputy Registrar – Academic

To,
1. The Dean, School of Chemical Sciences, Goa University.
2. The Vice-Deans, School of Chemical Sciences, Goa University.
3. The Principals of Affiliated Colleges offering the Bachelor of Science in Chemistry Programme.

Copy to:
1. The Director, Directorate of Higher Education, Govt. of Goa
2. The Chairperson, BOS in Chemistry.
3. The Controller of Examinations, Goa University.
4. The Assistant Registrar, UG Examinations, Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

	(3T+1P) CHC-204 Physical Chemistry-I (3T+1P) CHC-205 Pharmaceutical Chemistry-I (2)									
V	CHC-300 Organic Chemistry-II (3T+1P) CHC-301 Inorganic Chemistry-II (3T+1P) CHC-302 Physical Chemistry-II (3T+1P)	CHC-321 (Minor Vocational-2 Chemistry of Food and Nutrients (3T+1P)				CHC-361 Summer Internship [2]				

Issued on: 21/11/2024

	CHC-303 Green Chemistry Techniques (2)									
VI	CHC-304 Advanced Organic Chemistry-I (3T+1P) CHC-305 Advanced Inorganic Chemistry-I (3T+1P) CHC-306 Advanced Physical Chemistry-I (3T+1P) CHC-307 Project (4)	CHC-322 (Minor Vocational-3) Instrumentation and Analysis (3T+1P)								

Issued on: 21/11/2024

Semester V
Name of the Programme : B.Sc. (Chemistry)
Course Code : CHC-300
Title of the course : Organic Chemistry II
Number of Credits : 3T+1P
Effective from AY : 2025-26

Prerequisites for the course	Students should have knowledge of organic reactions, stereochemistry, spectroscopy and natural products	
Course Objectives:	1. To predict aromaticity and mechanism for electrophilic aromatic substitution of benzene. 2. To understand the stereochemical reactions. 3. To acquire knowledge of carbohydrate and amino acid chemistry. 4. To understand and apply enolate chemistry. 5. To understand Infrared spectroscopy and solve problems based on it. 6. To understand mechanism of different name reactions and rearrangements.	
Content		**No. of hours**
	1. Aromaticity and electrophilic substitution reactions: Huckel's rule of Aromaticity (4n+2) Rule, 4n Rule for antiaromaticity, Electrophilic Aromatic substitution (w.r.t Benzene): Mechanism of Nitration, Sulphonation, Halogenation, Friedel – Crafts alkylation and acylation. Reactivity and orientation of activating, deactivating groups (ortho, para and meta effects) with examples.	**06**
	2. Stereochemical reactions Stereospecific and stereoselective reactions. Addition of bromine to 3-Hexene with mechanism. Regioselectivity in addition of hydrogen halides to alkenes: Markownikoff's and anti-Markownikoff's addition. Substitution reactions: SN1, SN2, SNi reactions with mechanisms. Elimination reactions: E1, E2, E1cb reactions with mechanism.	**07**
	3. Chemistry of Natural Products -I Amino Acids and Peptides: Terms: Zwitterion, Isoelectric point and Electrophoresis. Preparation of Amino Acids: Strecker synthesis, Gabriel's phthalimide. Synthesis of simple peptides (upto dipeptides) Bergmann's method. Carbohydrates: Classification and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, Osazone formation, Killiani Fischer synthesis.	**08**
	4. Infra-Red Spectroscopy in Organic Chemistry Principle of IR Spectroscopy (Hooke's law), types of molecular vibrations (Stretching and bending). Functional group region and Fingerprint region. Applications of IR Spectroscopy: Functional group analysis, detection of purity of sample, establishing the identity of an unknown molecule, Effect of H-bonding, conjugation, resonance and ring size on IR absorptions. To study	**06**

	the progress of a reaction. Problems based on IR spectroscopy (ketone, aldehyde, ester, acid & alcohol).	
	5. Chemistry of Enolates Chemistry of Enolates. Definition of enolate ion, acidity of carbonyl compounds, pka values, generation of enolate ion, role of bases in enolate ion formation, alkylation of carbonyl compounds with reference to cyclohexanone, acetone, ethylacetoacetate, malonic ester. Claisen condensation for preparation of ethylacetoacetate (reaction and mechanism). Keto-enol tautomerism of ethylacetoacetate. Malonic ester synthesis of carboxylic acids, ethylacetoacetate synthesis of ketones. Alkylation of 1,3-dithianes. Alkylation via enamine synthesis.	**10**
	6. Name Reactions and Rearrangements -I Reaction and mechanism of the following: Benzoin, Aldol, Knoevanagel, Michael addition. Rearrangement with mechanism: Beckmann, and Wolff. Reaction and two applications of Diekmann, Stobbe, Favorskii and Hofmann Rearrangement.	**8**
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations /industry visits/ self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. Kemp, W., *Organic spectroscopy*, 3rd ed., Palgrave Macmillan, New York, USA, 1991. 2. Pavia, D. L., Lampman, G. M. and Kriz, G. S., *Introduction to Spectroscopy*, 3rd ed., Thomson Learning, Fort Worth, USA, 2001. 3. Silverstein, R. M. and Webster, F., *Spectrometric Identification of Organic Compounds*, 5th ed., John Wiley & Sons, New York, USA, 2006. 4. Graham Solomons, T.W., Fryhle, C.B. and Snyder, S. A., *Organic chemistry*, 12th ed., John Wiley & Sons, New Jersey, USA, 2016. 5. McMurry, J., *Fundamentals of organic chemistry*, 7th ed., Cengage Learning India Edition, Noida, India, 2013. 6. Sykes, P., *A guidebook to mechanism in organic chemistry*, 6th ed., Longman Scientific & Technical, England, UK, 1985. 7. Finar, I. L., *Organic Chemistry* (Vol. I), 6th ed., Pearson Education, India, 1973. 8. Finar, I. L., *Organic Chemistry* (Vol. II), 3rd ed., Longmans, London, UK, 1964. 9. Morrison, R.T., Boyd, R.N. and Bhattacharjee, S. K., *Organic Chemistry*, 7th ed., Pearson, 2010. 10. Bahl, A. and Bahl, B.S., *Advanced Organic Chemistry*, S. Chand, New Delhi, India, 2012. 11. Carey, F., *Organic Chemistry*, 4th ed., McGraw Hill, New York, USA, 2000. 12. Bruice, P. Y., *Organic Chemistry*, 3rd ed., Pearson Education, Asia, 2014. 13. March, J., *Advanced Organic Chemistry*, 4th ed., John Wiley, New Jersey, USA, 2007. 14. Nasipuri, D., *Stereochemistry of Organic compounds - Principles and Applications*, 4th ed., New Academic Science, Kent, UK, 2012.	

	15. Eliel, E. L., *Stereochemistry of Carbon Compounds*, Tata McGraw-Hill, New York, USA, 1962. 16. Potapov, V. M., *Stereochemistry*, Mir Publishers, Moscow, Russia,1979. 17. Kalsi, P. S., *Spectroscopy of Organic compounds*, 6th ed., New Age International Publishers, New Delhi, India, 2004.

Number of Credits: 01 (Practicals)

Course Objectives:	1. To apply theoretical concepts to experiments. 2. To acquire hands on training in organic preparation experiments. 3. To acquire hands on training in organic qualitative analysis.	
Content		**No. of hours**
	I. Organic preparations List of organic preparations to be performed. Purification by recrystallization, calculation of % yield and determination of melting point. (**Any 5)** a) Chalcone from acetophenone and benzaldehyde b) Benzoin from Benzaldehyde c) Cinnamic acid from benzaldehyde d) Acetanilide from acetophenone oxime e) Hippuric acid from glycine f) *m*-dinitrobenzene from nitrobenzene g) diazoaminobenzene from aniline	**15**
	II. Organic Estimations experiments (Any 3) a) Estimation of acid and amide. b) Estimation of acid and ester. c) Estimation of number of acetyl groups. d) Estimation of Saponification value of castor oil.	**12**
	III. Interpretation of Infra-Red Spectra (Any 5) Benzoic acid, *p*-nitroaniline, benzil, chalcone, cinnamic acid, ethanol, acetone, acetophenone, ethyl acetate.	**03**
Pedagogy:	Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. Each of the experiments should be done individually by the students.	
References / Readings	1. Furniss, B. S., Hannaford, A. J., Smith P. W. G. and Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5thed., Pearson Education Ltd., London, UK 2011. 2. Pasto, D., Johnson C. and Miller, M., *Experiments and Techniques in Organic Chemistry*, 1st ed., Prentice Hall, New Jersey, USA, 1992. 3. Fieser, L. F. and Williamson, K. L., *Organic Experiments*, 7th ed., D. C. Heath and Company, Massachusetts, USA,1992. 4. Bansal, R. K., *Laboratory Manual of Organic Chemistry*, 5th ed., New Age International Publishers, New Delhi, India, 2016.	
Course Outcome:	At the end of the course, students will be able to: 1. Identify aromatic, antiaromatic and non-aromatic compounds and explain stereochemistry of organic reactions. 2. Apply enolate chemistry in reaction mechanisms. 3. Write mechanism for name reactions and rearrangements.	

	4. Interpret Infrared spectra of organic compounds. 5. Synthesize some organic compounds. 6. Identify the functional groups present in organic compounds using Infrared spectroscopy. 7. Estimate organic compounds quantitatively. 8. Apply theoretical knowledge in understanding laboratory skills.

Name of the Programme : **B.Sc. (Chemistry)**
Course Code : **CHC-301**
Title of the course : **Inorganic Chemistry - II**
Number of Credits : **3T+1P**
Effective from AY : **2025-26**

Pre-requisites for the Course	Student should have knowledge of periodic properties, solid state chemistry and coordination chemistry	
Course Objectives:	1. To study the preparations, chemical properties, structure and bonding of halogen compounds. 2. To understand fundamentals of the metal ligand bond in accordance with VBT and CFT. 3. To learn the fundamentals of solid-state chemistry, superconductivity and to study their applications. 4. To comprehend the concepts of acid bases and non-aqueous solvents.	
Content		**No of hours**
	1. Chemistry of halogens Introduction to Group 17: General methods of preparation, structure, bonding and chemical properties of: i) Interhalogens ii) Polyhalides ions iii) Oxoacids of halogens in different oxidation states	**08**
	1. Coordination Chemistry-I Valence Bond Theory: Hybridisation of the central metal orbitals sp^3, dsp^2, sp^3d/dsp^3, sp^3d^2/d^2sp^3 Inner and Outer orbital complexes (suitable examples), electroneutrality principle and limitations of Valence Bond Theory. Crystal field theory: Postulates, effect of crystal field on central metal valence orbitals in various geometries. splitting of *d* orbitals in octahedral and tetrahedral crystal fields. Crystal field splitting parameters Δ, factors affecting Δ, Spectrochemical series. Crystal Field Stabilization Energy (CFSE), calculation of CFSE, for octahedral complexes with d^1 to d^{10} metal ion configuration. Consequences of crystal field splitting on various properties such as ionic radii, hydration energy, lattice energy, enthalpies of formation, colour and magnetic properties. Limitations of CFT. Evidences for covalency in metal complexes: i) intensities of d-d transitions, ii) ESR spectrum of $[IrCl_6]^{2-}$, iii) Nephelauxetic effect iv) NMR spectra.	**15**
	3. Acid Bases and Non-aqueous Solvents Arrhenius theory, Lowry-Bronsted theory, Lux–Flood, Solvent systems and Lewis concept of Acids and Bases, HSAB Concept of Acids and Bases, Classification of solvents and importance of non-aqueous solvents. Supercritical carbon dioxide and ionic liquids as solvents. Levelling effect, reactions in non-aqueous solvents with respect to liquid NH_3, liquid SO_2 and liquid HF.	**08**
	4. Introduction to Solid State Chemistry Structures of Solids: Importance of solid-state chemistry, types of solids, crystal lattice, lattice points, unit cells and lattice constants. Close packing of rigid spheres (hcp, ccp), packing density in simple	**10**

	cubic, bcc, fcc and hcp lattices (numerical problems expected). Relationship between density of unit cell and lattice parameters (numerical problems expected). Tetrahedral and octahedral interstitial voids in ccp lattice, limiting radius ratios of different coordination numbers and their significance. Calculation of limiting radius ratio for coordination number	
	5. Superconductivity Discovery of Superconductivity. Explanation of terms: Superconductivity, Transition temperature and Meissner effect. Different types of superconductors viz, conventional superconductors, organic superconductors, alkali metal fullerides and high temperature superconductors.	**04**
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / industrial visit, self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning	
References / Readings	1. P.L. Soni and Mohan Katyal, Textbook of Inorganic Chemistry by, Sultan Chand and Sons, 20th Edition (1997) 2. Puri, Sharma and Kalia, Principles of Inorganic Chemistry, 33rd Edition, Vishal Publishing Co. (2018). 3. J.D. Lee, Concise Inorganic Chemistry by Chaman and Hall, 5th ed. (1996). 4. J.C. Kotz, Paul M. Treichel, Grabriela C. Weaver, Chemistry and Chemical Reactivity, 6th Edn. Thomson Books/Cole (2006). 5. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.; Wiley, (Reprint 2008). 6. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, Pergamon Press, 1st Ed.; (1984). 7. Glen E. Rodgers, Inorganic Chemistry, 3rd Edn. Brooks/Cole (2012). 8. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, 3rd Edn. 9. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins, Inorganic Chemistry, 5th Ed.; Oxford Publications, (2009). 10. J.E. Huheey, E.A. Keiter, R.L. Keiter, U.K. Medhi, Inorganic Chemistry – Principles of structure and reactivity by, 1st impression (2006) Pearson Education Publishers. 11. K. V. S. Laxmi Devi, N. C. Patel, S.S. Dhume, A. Venkatachalam, S. P. Turakhia, Chhaya Dixit and R. A. Mirji, College Inorganic Chemistry for T.Y. B. Sc. 21st Edn, Himalaya Publishing House 12. Sharpe, Inorganic Chemistry, 3rd Edn. Pearson Education (2009). 13. Lesley E. Smart, Elaine A. Moore, Solid State Chemistry- An Introduction, 3rd Edn. Taylor and Francis, (2005)	

Practical	**Credits: 01**	
Course objectives	1. To use various titrimetric techniques to estimate the analytes. 2. To perform gravimetric methods to estimate metal ions. 3. To prepare coordination compounds.	
Content		
	Volumetric Analysis 1. Determination of the strength of the given H_2O_2 solution using N/20 $KMnO_4$ solution.	**2x4=8**

	2. Estimation of the amount of aluminium in the given aluminium sulphate solution by EDTA method (Back titration).	
	Gravimetric Analysis 3. Estimation of iron as Fe_2O_3 and Ba as $BaSO_4$ from the given solution of ferric chloride, barium chloride and free HCl. 4. Estimation of barium as $BaCrO_4$ and Fe as Fe_2O_3 from the given solution of barium chloride, ferric chloride and free HCl. 5. Estimation of Zn as zinc pyrophosphate in the solution of zinc chloride containing free HCl. 6. Estimation of Ni as Ni-DMG in the solution of nickel chloride containing copper chloride and free HCl.	**4x4 = 16**
	Inorganic Preparations (ANY TWO) 7. Bis-(ethylenediamine)copper (II) sulphate. 8. Preparation of diaquabis-(acetylacetonato)nickel (II) 9. Preparation of tris-(ethylenediamine)nickel (II) thiosulphate	**2x3 = 6**
Pedagogy:	1. Students shall be given pre-lab and post-lab assignments 2. Theoretical concept underlying the experiments prior to each experiment. 3. Each student shall perform the experiments independently.	
References / Readings	1. Svehla G. Vogel's Qualitative Inorganic analysis. Seventh Edition. Pearson Education Ltd. 2. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th Edn. Pearson Education. 3. O. P. Pandey, D. N. Bajpai and S. Giri, Practical Chemistry, Revised Edn. S. Chand.	
Course Outcomes	At the end of the course, students will be able to: 1. explain the preparations, chemical properties, structure and bonding in halogen compounds. 2. apply and differentiate VBT and CFT approaches for Metal-ligand bonding. 3. explain the fundamentals of solid-state chemistry, superconductivity and their applications. 4. correlate the concepts of acid bases and non-aqueous solvents 5. perform the redox and complexometric titrations. 6. explain the chemistry behind the strategies used for the removal of interfering ions in gravimetric estimations. 7. develop experimental skills in inorganic preparations.	

Name of the Programme : **B.Sc. Chemistry**
Course Code : **CHC – 302**
Title of the course : **Physical Chemistry II**
Number of Credits : **3T+1P**
Effective from AY : **2025-26**

Pre-requisites for the Course	Students should have studied electrochemistry, quantum chemistry and spectroscopy	
Course Objectives:	1. To introduce the fundamentals of electrochemistry. 2. To understand and apply the concepts of quantum mechanics. 3. To learn the principles of vibrational and rotational spectroscopy.	
Content		**No of hours**
	1. Electrochemistry-I Conductivity: Equivalent and molar conductivity and the effect of dilution for weak and strong electrolytes. Arrhenius theory of ionisation, Ostwald dilution law. Debye-Hückel theory and its limitation. Debye Hückel-Onsager equation. Kohlrausch's law of independent migration of ions. Ionic mobility and factors affecting ionic mobility. Transference number and its experimental determination using moving boundary methods, Hittorf method. Applications of conductance measurements: hydrolysis and hydrolysis constant, solubility and solubility products of sparingly soluble salts, ionic product of water, conductometric titrations (only acid-base). EMF of a cell and its measurements, reversible cells and irreversible cells, types of reversible electrodes. Concentration cells (both electrodes and electrolytes) with and without transference, liquid junction potential and its measurements. (Numericals to be solved)	**15**
	2. Quantum Chemistry-I De-Broglie hypothesis, experimental verification of De Broglie Hypothesis, Heisenberg uncertainty principle, Derivation of Heisenberg's uncertainty principle, sinusoidal wave function, eigen value and eigen functions, physical significance of wave function. Terms involved in Quantum mechanics: Normalisation, orthogonality, observables, degeneracy, forbidden transitions and stationary state, Operators (linear, non-linear, Hermitian, non-Hermitian, Hamiltonian Operator) and commutation rules, Postulates of quantum mechanics, Schrödinger equation and its application to free particle and "particle in a box" (rigorous treatment), quantisation of energy levels, zero – point energy. (numericals to be solved).	**15**
	3. Molecular Spectroscopy -I Interaction of electromagnetic radiation with molecules and various types of spectra, Born-Oppenheimer approximation. a. Rotational Spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution. b. Vibrational spectroscopy: Classical equation of vibration, computation of force constant, anharmonicity, Morse potential,	**15**

	dissociation energies, fundamental frequencies, overtones, hot bands, degree of freedom for polyatomic molecules, modes of vibration (H_2O and CO_2), concept of group frequencies. Vibration–rotation spectroscopy: Diatomic vibrating rotator, P, Q, R branches. c. Raman spectroscopy: Raman effect, qualitative treatment of Rotational Raman effect, Vibrational Raman spectra, Stokes and Anti-stokes lines, their intensity difference, Quantum and Classical theories of Raman effect, rule of mutual exclusion principle. (numericals to be solved)	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations/ self-study or a combination of some of these can also be used. ICT modeshould be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings, References for practicals	1. Banwell, C.N. & McCash, E.M., Fundamentals of Molecular Spectroscopy, 4th edition, Tata McGraw Hill, New Delhi, 2006. 2. Ira N. Levine, Quantum chemistry, 7th edition, Pearson India Education Pvt. Ltd., 2016, Noida. 3. Donald A. McQuarrie, John D. Simon, Physical Chemistry: A Molecular Approach, Student Edition, Viva Books Pvt. Ltd., 2018, Mumbai, 1st edition. 4. J.N. Gurtu, Physical Chemistry Vol-III, A Pragati Prakashan edition, 2020, Meerut, 9th edition. 5. N. B. Laxmeshwar, S. M. Malushte, A. S. Mulye, V. N. Kulkarni, Concepts of Physical Chemistry, Chetana Prakashan, Girgaon, Mumbai, 5th edition, 1994. 6. Gurdeep Raj, Advanced Physical Chemistry Goel Publication 36th Edition, 2010, Meerut. 7. Chandra, A.K., Introductory Quantum Chemistry, Tata McGraw –Hill (2001), New Delhi, 4th edition. 8. J. E. House, Fundamentals of Quantum Chemistry, 2nd edition, Elsevier, USA, 2004. 9. Lowe. J.P. & Peterson., K., Quantum Chemistry, Academic Press, 2005, USA, 3rd edition.	

Practicals: Credits: 01

Course Objectives:	1. To understand the different techniques in electrochemistry. 2. To acquire knowledge of the types of spectra. 3. To obtain information on plotting wave functions.	
Content		**No of hours**
	1. To determine the cell constant using 0.1N and 0.02N KCl solution.	**2**
	2. To verify Ostwald's dilution law using acetic acid.	**4**
	3. To determine the percentage composition of acid mixture (strong acid and weak acid) by titrating against standard 0.1N NaOH.	**4**
	4. To determine standard oxidation potential of Cu/Cu^{+2} and Zn/Zn^{+2}	**4**
	5. To determine solubility product of AgCl using potentiometer.	**4**
	6. To determine formal redox potential of Fe^{+2}/Fe^{+3} system using 0.1N $K_2Cr_2O_7$.	**4**
	7. To plot the orthonormal wavefunctions of a particle in a one-dimensional box.	**4**

	8. Using vibrational-rotational spectra of HCl and HBr molecules a) Assign the rotational lines to various transitions. b) Calculate: i) The value of B_0 and B_1, for R and P branches of spectra ii) Vibrational frequency and iii) Internuclear distance.	**4**
Pedagogy	Students should be given suitable explanation revising the theoretical aspects prior to the conduct of each experiment. Pre- and post-laboratory assignments to be given. Each student performs the experiment individually.	
References / Readings, References for practicals	1. W. Rajbhoj and T.K. Chondhekar, Anjali Publication, Systematic experimental Physical Chemistry, 2000, Aurangabad, 2nd edition. 2. P. S. Sindhu, Practicals in Physical Chemistry, Macmillan India Publication, 2006, New Delhi, 1st edition. 3. B. Viswanathan and P.S Raghavan, Practical Physical Chemistry, Viva Books Private Ltd, 2005, Mumbai. 4. Khosla, B. D.; Garg, V. C. &Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co., New Delhi, 2018, 18th edition	
Course Outcome:	At the end of the course, students will be able to: 1. differentiate between the types of cells used in electrochemistry. 2. use quantum operators for solving numericals. 3. identify and predict structure of molecules using vibrational and rotational spectra. 4. perform conductometric and potentiometric measurements. 5. measure standard oxidation potentials of various metal/metal ion electrodes. 6. calculate internuclear distance of molecules from vibrational-rotational spectra.	

Name of the Programme : **B.Sc. (Chemistry)**
Course Code : **CHC-303**
Title of the course : **Green Chemistry Techniques**
Number of Credits : **2T**
Effective from AY : **2025-26**

Prerequisites for the course	Should have knowledge of chemical reactions	
Course Objectives:	1. To understand solvent-free and safer solvent organic reactions. 2. To demonstrate the role of green catalysis in organic reactions. 3. To acquire knowledge on modern green techniques.	
Content		**No of hours**
	Introduction to Green chemistry and 12 principles	**01**
	Mechanogrinding and safer solvents Solvent free reaction: Grinding Techniques-Aldol condensation between 3,4-dimethoxybenzaldehyde and 1-indanone. Procedure, advantages and drawbacks. Ball milling technique, Principle, instrumentation, working, advantages, disadvantages, one application. Water as green solvent with an example-Diels Alder reaction-Theory on how water works as solvent, advantages, disadvantages. Supercritical liquids: Procedure for extraction of D-limonene from orange peels. Advantages of using $ScCO_2$. Ionic liquids as designer solvent giving reasons. Preparation of [Bimim] BF_4^-, example giving reaction using ionic liquids-Green preparation of 1-acetyl ferrocene. Deep eutectic solvent- Properties and one application with example of choline chloride and urea.	**09**
	Green Catalysis Define catalysis. Types of catalysis, homogeneous and heterogeneous. Types of green catalysis Definition: Solid supported reagents- Advantages and disadvantages, examples $NaBH_4$- Alumina and PCC-silica giving one application of each. Biocatalyst or natural catalysts-Thiamine hydrochloride in benzoin condensation and L-Proline for enantioselective aldol reaction (only reaction to be given). Advantages of L-Proline and Thiamine HCl. Phase transfer catalysis: Definition, Phase Transfer catalyst, Mechanism of PTC, Advantages and application in Chemistry-Using 18-crown-6 ether or ammonium salt.	**10**
	Modern Green Techniques Microwave heating technique: Principle-Convection, dipolar ionisation, working, advantages and limitations. Green synthesis of metallophthalocyanine complexes with reaction and procedure. Ultrasonication technique: Principle-Acoustic Cavitation with diagram, working, advantages and limitations. Preparation of Grignard reagent by ultrasonication method. Photochemistry: Principle of photochemical reaction. Organic photochemical reactions with two examples. Role as a green technique-Advantages and drawback.	**10**

	Electrochemistry: Principle of an electrochemical reaction. Electrochemical set up diagram. One application, advantages and limitations. Flow Chemistry: Principle, one application. Advantages over batch process.	
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations /industry visits/ self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. Anastas, P. T., and Warner, J. K., *Green Chemistry-Theory and Practice*, Oxford University Press, UK, 2000. 2. Sharma, R. K., Sidhwani, I. T., and Chaudhari, M. K., *Green Chemistry Experiments: A monograph,* I. K. International Publishing House Ltd. New Delhi, 2012. 3. Ahluwalia, V. K., *Green Chemistry: Environmentally Benign Reactions*, Anne Books India, New Delhi, 2006. 4. Cann, M. C., and Connely, M. E., *Real-World cases in Green Chemistry*, American Chemical Society, Washington, 2000. 5. Waber, W. P., and Gokel, G. W., *Phase Transfer Catalysis in Organic Synthesis*, Springer Berlin, Heidelberg, 1977. 6. Ahluwalia, V. K., and Aggarwal, R., *Organic Synthesis-Special Techniques*, Narosa Publishing House, New Delhi, 2001. 7. Kappe, C. O., Stadler, A., and Dallinger, D., *Microwaves in Organic and Medicinal Chemistry,* Second revised edition, John Wiley & Sons, Darmstadt, Germany, 2012. 8. Ahluwalia V.K., and Kidwai M., *New trends in Green Chemistry*, Kluwer Academic Publishers, Dordrecht, The Netherlands, 2004. 9. Vacarro, L., *Sustainable flow chemistry: methods and Applications*, John Wiley and Sons Publishers, Weinheim, Germany, 2017. 10. Darvas, F., Hessel, V., and Dorman, G., *Flow Chemistry Vol 1 and II (Fundamentals and Applications)*, Walter de Gruyter GmbH & Co KG, Germany, 2014. 11. Desai, K. R., *Green Chemistry Microwave synthesis*, revised edition, Himalaya Publishing house, India, 2010. 12. Pletcher, D., *Guide to Electrochemical Technology for Synthesis, Separation and Pollution Control,* Electrosynthesis Company, Inc., Lancaster, NY,1999. 13. Rohatgi-Mukherjee, K. K., *Fundamentals of Photochemistry*, revised second edition, New Age International Publishers, New Delhi, 2006. 14. DuPay, C. H., and Chapman, O. L. *Molecular Reactions and Photochemistry*, Englewood Cliffs, N. J., Prentice-Hall, Englewood Cliffs NJ, 1972. 15. Crow, D. R., *Principles and Applications of Electrochemistry*, Fourth Edition, CRC Press, Boca Raton, FL, USA, 1994.	
Course Outcome:	At the end of the course, students will be able to 1. Apply the knowledge of safer solvents in designing synthesis of organic compounds. 2. Demonstrate the role of catalysis in organic synthesis 3. Apply the knowledge of modern green techniques in organic synthesis.	

Semester - VI
Name of the Programme : B.Sc. (Chemistry)
Course Code : CHC-304
Title of the course : Advanced Organic Chemistry I
Number of Credits : 3T+1P
Effective from AY : 2025-26

Prerequisites for the course	Students should have knowledge of spectroscopy, natural products and organic reactions	
Course Objectives:	1. To acquire knowledge of natural product chemistry and heterocyclic chemistry. 2. To understand NMR spectroscopy and solve problems on structure elucidation. 3. To understand mechanism of name reaction and rearrangements.	
Content		**No. of hours**
	1. Chemistry of Heterocyclic compounds Definition of heterocyclic compounds: Organic compounds containing oxygen, sulphur, nitrogen. Classification with examples for three, four, five and six membered heterocycles. Structure, resonance, stability and industrial source of furan, pyrrole, thiophene and pyridine. Preparation of furan, pyrrole and thiophene using Paal Knorr Synthesis. Reactivity of furan, pyrrole and thiophene: Electrophilic substitution at 2/5 position. (Nitration, Friedel-Crafts acylation, Sulphonation, Halogenation). Preparation of pyridine using Hantzsch synthesis. Reactivity of pyridine: Basicity order of pyrrole, pyridine and piperidine. Electrophilic substitution at 3 position. Nucleophilic substitution at 2/4 position. Definition of bicyclic heterocycles with examples. Structure, resonance, stability and industrial source of indole, quinoline, isoquinoline. Preparation of indole using Fischer indole synthesis. Reactivity of Indole: Electrophilic substitution at 3 position. Skraup synthesis of quinoline and Bischler Napieralski synthesis of isoquinoline. Electrophilic substitution at 5 and 8 positions.	**15**
	2. NMR Spectroscopy of Organic Compounds Basic Principles of ^{1}HNMR spectroscopy, Number of signals, Position of signals, Chemical shift: Reference standard, Solvent effect, Shielding and deshielding effect, anisotropic effects in alkenes, alkynes, aldehydes, aromatic compounds, factors affecting chemical shift. Intensity of signals: Peak area and proton counting. Spin-Spin coupling: Coupling constant (J). Interpretation of NMR spectra of simple compounds. (acetone, acetaldehyde, toluene, ethyl bromide, anisole, acetic acid, *t*-butylbenzene, 2-butanone, propene). Simple problems based on NMR spectral data for identification of molecule. Carbon-13 Nuclear Magnetic Resonance Spectroscopy Principle of ^{13}C spectroscopy. Number of signals: Proton coupled and decoupled spectra (off-resonance). Position of signals. Factors affecting position of signals (hybridisation).	**12**

	Combined Problems based on UV, IR, ^{1}HNMR and ^{13}CNMR spectroscopy.	
	3. Chemistry of Natural Products -II Terpenes: General classification of terpenes, isoprene rule, special isoprene rule. General methods of structure elucidation. Structure elucidation of α-Terpineol. Synthesis of Terebic acid and terpenylic acid. Synthesis of *α* –Terpineol from *p*-toluic acid. Alkaloids: General methods of structure elucidation. Ziesel's Method, Herzig-Meyer's method, Hoffman's exhaustive methylation method. Structure elucidation of Nicotine. Synthesis of Nicotine from Succinimide. Vitamins and Hormones: Structure elucidation of Vitamin A and Adrenaline. Synthesis of Vitamin A from *β*-ionone and Adrenaline from Catechol.	**12**
	4. Name Reactions and Rearrangements -II Reaction and mechanism of the following: Wittig and Darzens Glycidic ester. Rearrangement with mechanism: Claisen, Curtius. Reaction and two applications of Baeyer Villiger, Appel. Comparison of Clemmensen reduction and Wolff-Kishner reduction with two examples.	**06**
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations /industry visits/ self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings	1. Kemp, W., *Organic spectroscopy*, 3rd ed., Palgrave Macmillan, New York, USA, 1991. 2. Pavia, D. L., Lampman, G. M. and Kriz, G. S., *Introduction to Spectroscopy*, 3rd ed., Thomson Learning, Fort Worth, USA, 2001. 3. Silverstein, R. M. and Webster, F., *Spectrometric Identification of Organic Compounds*, 5th ed., John Wiley & Sons, New York, USA, 2006. 4. Graham Solomons, T.W., Fryhle, C.B. and Snyder, S. A., *Organic chemistry*, 12th ed., John Wiley & Sons, New Jersey, USA, 2016. 5. McMurry, J., *Fundamentals of organic chemistry*, 7th ed., Cengage Learning India Edition, Noida, India, 2013. 6. Sykes, P., *A guidebook to mechanism in organic chemistry*, 6th ed., Longman Scientific & Technical, England, UK, 1985. 7. Finar, I. L., *Organic Chemistry* (Vol. I), 6th ed., Pearson Education, India, 1973. 8. Finar, I. L., *Organic Chemistry* (Vol. II), 3rd ed., Longmans, London, UK, 1964. 9. Morrison, R.T., Boyd, R.N. and Bhattacharjee, S. K., *Organic Chemistry*, 7th ed., Pearson, Bangalore, India, 2010. 10. Bahl, A. and Bahl, B.S., *Advanced Organic Chemistry*, S. Chand, New Delhi, India, 2012. 11. Carey, F., *Organic Chemistry*, 4th ed., McGraw Hill, New York, USA, 2000. 12. Bruice, P. Y., *Organic Chemistry*, 3rd ed., Pearson Education, Asia, 2014. 13. March, J., *Advanced Organic Chemistry*, 4th ed., John Wiley, New Jersey, USA, 2007.	

	14. Nasipuri, D., *Stereochemistry of Organic compounds - Principles and Applications*, 4th ed., New Academic Science, Kent, UK, 2012. 15. Eliel, E. L., *Stereochemistry of Carbon Compounds*, Tata McGraw-Hill, New York, USA, 1962. 16. Potapov, V. M., *Stereochemistry*, Mir Publishers, Moscow, Russia,1979. 17. Kalsi, P. S., *Spectroscopy of Organic compounds*, 6th ed., New Age International Publishers, New Delhi, India, 2004. 18. Dyer, J. R., *Applications of Absorption Spectroscopy of Organic compounds*, Prentice Hall of India, New Delhi, India, 1974. 19. Parikh, V.M., *Absorption spectroscopy of organic Molecules*, Addison Wesley Publishing Company, Massachusetts, USA,1974. 20. Williams, D.H and Fleming, I., *Spectroscopic methods in organic chemistry*, 7th ed., Springer Nature, Switzerland, 2019. 21. Joule, J. A. and Mills, K., *Heterocyclic chemistry*, 5th ed., Wiley-Blackwell, New Jersey, USA, 2010. 22. Ahluwalia, V. K. and Parashar, R.K., *Organic Reaction Mechanisms*, 3rd ed., Alpha science International, Oxford, UK, 2006.

Number of Credits: 01 (Practicals)

Course Objectives:	1. To apply theoretical concepts to experiments. 2. To acquire hands on training in organic preparation. 3. To acquire hands on training in organic qualitative analysis.	
Content		**No. of hours**
	I) Binary mixture separation (7 mixtures to be done) a) Solid-solid mixture (3) water insoluble+ water insoluble (2). water soluble +water insoluble (1). b) Solid-liquid mixture (2) c) Liquid-liquid mixture (2)	**28**
	II) Interpretation of ^{1}H and ^{13}C NMR Spectra (Any 2 compounds) (benzoic acid, acetone, benzaldehyde, ethanol, toluene, ethyl acetate, isopropyl benzene).	**02**
Pedagogy	Students should be given suitable pre- and post-lab assignments and explanation revising the theoretical aspects of laboratory experiments prior to the conduct of each experiment. Each of the experiments should be done individually by the students.	
References / Readings	1. Furniss, B. S., Hannaford, A. J., Smith P. W. G. and Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5thed., Pearson Education Ltd., London, UK, 2011. 2. Pasto, D., Johnson C. and Miller, M., *Experiments and Techniques in Organic Chemistry*, 1st ed., Prentice Hall, New Jersey, USA,1992. 3. Fieser, L. F. and Williamson, K. L., *Organic Experiments*, 7th ed., D. C. Heath and Company, Massachusetts, USA, 1992. 4. Bansal, R. K., *Laboratory Manual of Organic Chemistry*, 5th ed., New Age International Publishers, New Delhi, India, 2016.	
Course Outcomes	At the end of the course, students will be able to: 1. Explain the chemistry of simple heterocyclic compounds. 2. Interpret NMR spectra and elucidate structure of organic compounds. 3. Explain chemistry of selected natural products.	

	4. Write mechanism for selected name reactions and rearrangements. 5. Analyse and identify the structure of organic compounds using NMR spectroscopy. 6. Separate unknown organic mixture and identify the compounds. 7. Apply theoretical knowledge in understanding laboratory skills.

Name of the Programme : **B.Sc. (Chemistry)**
Course Code : **CHC-305**
Title of the course : **Advance Inorganic Chemistry - I**
Number of Credits : **3T+1P**
Effective from AY : **2025-26**

Pre-requisites for the Course	Students should have studied coordination chemistry and solid-state chemistry	
Course Objectives:	1. To study the theories of metal-ligand bonding in coordination compounds 2. To comprehend the different electronic transitions, ground state terms, and term symbols. 3. To learn about the organometallic compounds and metal complexes in biological systems 4. To study the properties and applications of nanomaterials.	
Content		**No of hours**
	1. Co-ordination Chemistry II Ligand Field Theory (Adjusted Crystal Field Theory), Molecular Orbital Theory (MOT) of Coordination Compounds: Identification of central metal orbitals and their symmetry suitable for formation of σ-bonds with ligands orbitals. Construction of ligand group orbitals. Construction of σ-molecular orbitals for an ML_6 complex. Molecular orbitals diagrams of $[Ti(H_2O)_6]^{+3}$, $[Fe(CN)_6]^{-3}$, $[FeF_6]^{-3}$ and $[Co(NH_3)_6]^{+3}$ complexes. Effect of π - bonding on splitting parameter. Comparison of the CFT and MOT. Thermodynamic stability and kinetic stability of complexes with examples. Stability constants: Stepwise and overall stability constants and their inter-relationship. Factors affecting thermodynamic stability.	**10**
	Organometallic Chemistry General characteristics of various types of organometallic compounds, viz, ionic, sigma-bonded and electron-deficient compounds. EAN rule, 18 electron rule. Metal carbonyls: Preparation, properties, structure and bonding in mononuclear metal carbonyls. Polynuclear metal carbonyl: Preparation and structures of $Mn_2(CO)_{10}$, $Co_2(CO)_8$ $Fe_2(CO)_9$ and $Fe_3(CO)_{12}$. Metallocenes: Introduction, Ferrocene: synthesis, properties, structure and bonding on the basis of VBT and MOT.	**10**
	3. Magnetism and Electronic Spectra of Coordination Compounds A) Magnetism: Introduction, types, origin of magnetism, spin-only formula and calculation of magnetic moment, determination of magnetic susceptibility by Guoy's method, applications of magnetic moment data for 3d complexes. B) Electronic Spectra: Origin, types of electronic transitions in coordination compounds: intra–ligand, charge transfer and intra-metal transitions. Selection rules: Spin and Laporte selection rules and intensities of spectra. Electronic	**15**

	configuration, microstates, Ground state terms, and Term symbols. Coupling of spin momenta (Ms), orbital momenta (M_l), and spin-orbit coupling or Russell-Saunders coupling. Orgel Diagrams for d^1/d^9 and d^2/d^8 electronic configurations in octahedral coordination compounds.	
	4. Bioinorganic and Medicinal Chemistry Metal coordination in biological systems: Enzymes, apoenzymes and coenzymes. Biological role of carboxypeptidases, catalases and peroxidases. Metal complexes in medicine: carboplatin, oxaliplatin and gold complexes. Inorganic radiopharmaceuticals: Introduction, diagnostic and therapeutic uses with reference to Mo, Tc, I, Lu isotopes.	**05**
	5. Nanomaterials Introduction and importance of nanomaterials, quantum confinement and surface effects. Chemical methods of synthesis of nanomaterials. Characterization of nanomaterials (UV, XRD, TEM techniques). Dimensions and forms of nanomaterials: nanofilms, nanolayers, nanotubes, nanowires, and nanoparticles. Properties and applications of nanomaterials.	**05**
Pedagogy	1. Lectures and Tutorials. 2. Seminars/Term papers/Assignments/Applicative Quiz sessions/ Presentations. 3. Industry visits/self-study or a combination of some of these can be used. 4. ICT mode will be preferred. 5. Sessions should be interactive in nature to enable peer group discussions and learning.	
References / Readings	1. J.D. Lee, Concise Inorganic Chemistry by, Chaman, and Hall, 5th ed. (1996). 2. F. A. Cotton, G. Wilkinson, P. L. Gauss, Basic Inorganic Chemistry, 3rd Ed.; Wiley, (Reprint 2008). 3. N. N. Greenwood, A. Earnshaw, Chemistry of the Elements, Pergamon Press, 1st Ed.; (1984). 4. Glen E. Rodgers, Inorganic Chemistry, 3rd Edn., Brooks/Cole (2012). 5. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, 3rd Edn. Wiley Eastern Ltd., (1993) 6. P. W. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong, Shriver & Atkins Inorganic Chemistry, 5th Ed.; Oxford Publications, (2009). 7. J.E. Huheey, E.A. Keiter, R.L. Keiter, U.K. Medhi, Inorganic Chemistry – Principles of structure and reactivity by, 1st impression (2006) Pearson Education Publishers. 8. K. V. S. Laxmi Devi, N. C. Patel, S.S. Dhume, A. Venkatachalam, S. P. Turakhia, Chhaya Dixit and R. A. Mirji, College Inorganic Chemistry for T.Y. B. Sc. 21st Edn, Himalaya Publishing House 9. A. Sharpe, Inorganic Chemistry, 3rd Edn. Pearson Education (2009). 10. Lesley E. Smart, Elaine A. Moore, Solid State Chemistry- An Introduction, 3rd Edn. Taylor and Francis, (2005) 11. B. Douglas, D. Mc. Daniels, J. Alexander, Concepts, Models of inorganic chemistry by, Mohan Wiley & Sons 3rd Edn (2007).	

	12. R. L. Dutta, A. Syamal, Elements of Magnetochemistry, 2nd Ed.; Affiliated East-West Press, New Delhi (1993) 13. Gary Wulfsberg, Inorganic chemistry, Viva Books Pvt, Ltd. (2002). 14. Ajay Kumar and G.R. Chatwal, Bio-inorganic and Supramolecular Chemistry, 1st edn. Himalaya Publishing House (Reprint 2022). 15. Brechignac, P. Houdy, M. Lahmani, Nanomaterials and Nanochemistry, Springer (2006) 16. A.H. Beckett, J.B. Stenlake, Practical Pharmaceutical Chemistry (Part 2), 1st edn. CBS Publishers and Distributors, New Delhi (Reprint 2005). 17. Sibaprasad Bhattacharyya, Inorganic Pharmaceuticals for Imaging and Therapy: Current Trends and Future Directions, Encyclopaedia of Inorganic and Bioinorganic Chemistry, John Wiley and Sons (2016) doi.org/10.1002/9781119951438.eibc2464 18. Valerie Carroll, Dustin W. Demoin, Timothy J Hoffman and Silvia S Jurisson, Inorganic chemistry in nuclear imaging and radiotherapy: current and future directions, Radiochim Acta. 2012 August; 100 (8-9): 653–667. doi: 10.1524/ract.2012.1964	
Practicals: Credits: 01		
Course Objectives:	1. To prepare inorganic coordination compounds. 2. To use various titrimetric techniques to estimate the analytes.	
Content		**30hr**
	1. Preparation of tetraamminecopper (II) sulphate 2. Preparation of tris-(acetylacetonato)iron (III) 3. Estimation of Fe(III) by dichromate method in the given solution of ferric alum by using $SnCl_2$. 4. Estimation of nitrite present in the given $NaNO_2$ solution by using ceric ammonium sulphate. 5. Determination of the strength (grams/litre) of $AgNO_3$ solution using N/30 NaCl solution by Mohr's Method. 6. Estimation of magnesium content in talcum powder by complexometric titration (EDTA method). 7. Determination of acetic acid in commercial vinegar by titrating with approx. 0.05N NaOH solution. 8. Estimation of copper from tetraaminecopper (II) sulphate complex by iodometry. 9. Estimation of sodium carbonate content of washing soda. 10. Determination of hardness of water from given sample by complexometric method.	**10 x3 =30**
Pedagogy	1. Students shall be given pre-lab and post-lab assignments. 2. Theoretical concept underlying the experiments prior to each experiment. 3. Each student shall perform the experiments independently.	
References / Readings	1. J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, B. Sivasankar, Vogel's Textbook of Quantitative Chemical Analysis, 6th edn., Pearson Education. 2. O. P. Pandey, D. N. Bajpai and S. Giri, Practical Chemistry, Revised Edn., S. Chand. 3. George Brauer, Handbook of Preparative Inorganic Chemistry Vol. 2, 2nd Edition, Academic Press (1964)	

Course outcomes	At the end of the course, students will be able to: 1. explain the electronic spectra, magnetism, and thermodynamic/ kinetic stability of coordination compounds and the biological significance of metal complexes. 2. explain the properties of nanomaterials with their bulk counterpart. 3. construct the molecular orbital diagram for coordination compounds. 4. apply EAN and 18 electron rule to explain the stability of organometallic compounds. 5. prepare normal and molar solutions of a substance. 6. calculate the amount of substance in given solutions. 7. perform volumetric experiments to determine unknown concentrations. 8. estimate metal ion contents from given samples.

Name of the Programme : **B.Sc. (Chemistry)**
Course Code : **CHC – 306**
Title of the course : **Advanced Physical Chemistry-I**
Number of Credits : **3T+1P**
Effective from AY : **2025-26**

Pre-requisites for the course	Students should have studied surface chemistry, colloids and electrochemistry	
Course Objectives:	1. To empower the students with applied physical chemistry skills for industrial applications. 2. To introduce heterogeneous catalysis and its importance in chemical industry. 3. To understand the principles and applications of energy sources.	
Content		**No of hours**
	1. Catalysis and Surface chemistry General Introduction: Catalysis and activation energy. Homogeneous vs Heterogeneous catalysis with suitable examples. Catalytic activity, selectivity and stability. Steps in a heterogeneous catalysis reaction. Adsorption vs absorption, cause of adsorption, striking and sticking probability. Freundlich and Langmuir adsorption isotherms and their application in waste water purification. Types of catalyst. Precipitation and combustion method of catalyst synthesis. Metal catalysed reactions (Haber-Bosch process of NH_3 synthesis), solid acid and solid base catalysts in industrial reactions (alkylation, dehydration, amination and xylenol production reactions). Introduction to zeolites and zeolite catalyzed industrial reactions (examples with illustrations to be discussed).	**10**
	2. Colloids and surfactant technology General introduction to colloids, classification and types, electrical double layer, DLVO theory, colloidal stability, surfactants and reduction of surface tension, charged colloids, electrokinetic phenomena and zeta potential of colloids. Preparation of colloids: hot injection method for synthesis of colloidal semiconductor nanocrystals/ quantum dots. Industrial methods of colloid synthesis. Applications of colloids: (i) Colloids as drug delivery agents in the form of liposomes, (ii) thin film processing of colloidal nanocrystal for their applications in LEDs, biological imaging.	**10**
	3. **Electrochemistry II** **b.** Applications of emf measurements-(i) determination of pH using hydrogen electrode, quinhydrone electrode, glass electrode, (ii) determination of solubility and solubility product of sparingly soluble salts, (iii) determination of ionic product of water (iv) determination of transport number. Polarisation; elimination of polarization; decomposition potential; measurement of decomposition potential; overvoltage and types of overvoltage; measurement of overvoltage; factors affecting overvoltage; Tafel plot. Buffer solution, types, buffer action, buffer capacity, and mechanics of buffer action, Henderson equation for acidic and	**15**

	basic buffer. Debye Hückel theory of strong electrolytes. Variation of activity coefficient with concentration, ionic strength, Debye Hückel limiting law.	
	b. Energy sources: i) Batteries: Introduction to batteries, primary and secondary battery, basic principles; rating and shelf life. Leclanché and Lead acid battery, Lithium ion batteries and rechargeability. ii) Supercapacitors: Introduction to Supercapacitors, types of Supercapacitors, EDLC and Pseudocapacitors. Advantages and limitations of supercapacitors. iii) Photovoltaics: Solar cell, construction, working, advantages and disadvantages of silicon solar cell. iv) Fuel cells; H_2-O_2 fuel cell, molten carbonate fuel cell, proton exchange membrane fuel cell, solid-oxide fuel cell. (numericals are expected)	**10**
Pedagogy	Mainly lectures and tutorials. Seminars / term papers /assignments / presentations / self-study or a combination of some of these can also be used. ICT mode should be preferred. Sessions should be interactive in nature to enable peer group learning.	
References / Readings, References for practicals	1. J. O. M. Bockris & A. K. N. Reddy, Modern Electrochemistry, Springer India Pvt. Ltd, 2000, Vol.1, 2 and 3., New Delhi, 2nd edition. 2. A. Vincent & B. Sacrosati, Modern Batteries, John Wiley, NewYork,1997, 2nd edition. 3. J. O. M. Bockris & S. Srinivasan, Fuel cells: Their Electrochemistry, McGraw-Hill Book Co., 1969, New York. 4. B. A. J., Stratmann M. and Licht D, Encyclopedia of Electrochemistry, Semiconductor Electrodes and Photoelectrochemistry, Wiley-VCH, 2002 New Jersey. 5. K. S. Birdi, Surface and Colloid Chemistry: Principles and Applications, Taylor & Francis Group, 2010, UK, 1st edition. 6. V. Lesnyak, M. Yarema, S. Miao, Colloidal Semiconductor Nanocrystals: Synthesis, Properties and Applications, Frontiers Media SA, 2020 Switzerland. 7. B. E. Conway, Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications, Springer, New York, 1999. 8. M. S. Halper and J. C. Ellenbogen, Supercapacitors: A Brief Overview, March 2006, MP 05W0000272 MITRE Nanosystems Group, Virginia. 9. B. Vishwanathan, S. Sivasanker and A. V. Ramaswamy, Catalysis: Principles and Applications, Narosa Publishing House, 2002, New Delhi, Illustrated Edition. 10. P. S. Farinas, A. L. Doimo, M. A. R. da Silva, and I. F. Teixeira, Journal of Chemical Education, 2020, 97 (10), 3771-3777. 11. J. N. Gurtu, Physical Chemistry, Vol-III, Pragati Prakashan, 2020, 9th edition, Meerut. 12. N. B. Laxmeshwar, S. M. Malushte, A. S. Mulye and V. N. Kulkarni, Concepts of Physical Chemistry, Chetana Prakashan, Mumbai, 5th ed,1994. 13. G. Raj, Advanced Physical Chemistry, Goel Publication, 36th edition, 2010, Meerut.	

	14. A. Bahl and G.D. Tuli, S., Essentials of Physical Chemistry, Chand Publication, 2019, New Delhi, 26th edition. 15. Puri Sharma and Pathania, Principles of Physical Chemistry, Vishal Publishing Co., 2018, Jalandhar, New-Delhi,1st edition 16. R. L Madan, Chemistry for degree students, S Chand publications, 2017, New Delhi, 1st edition. 17. P. C. Jain, Engineering Chemistry, Dhanpat Rai Publishers, 17th edition, New Delhi, 2020.

Practicals: Credit: 01

Course Objectives:	1. To use the theoretical concepts in performing the experiments. 2. To acquire knowledge on the types of electrodes used in potentiometry. 3. To calculate dissociation constant of mono basic acids	
Content		**No of Hours**
	1. Verification of Debye –Hückel Onsager equation using dilute solution of KCl by conductometric method.	**2**
	2. To determine the strength of mixture containing weak acid (CH_3COOH) and salt of weak base (NH_4Cl) by titrating against standard 0.1N NaOH solution conductometrically.	**4**
	3. To determine hydrolysis and hydrolysis constant of Sodium Acetate /NH_4Cl.	**4**
	4. To determine potentiometrically the equivalence point of strong acid v/s strong base using quinhydrone and amount of acid present.	**4**
	5. To determine the percentage composition and the amount of halides from a mixture (any two halides) using standard 0.1N $AgNO_3$.	**4**
	6. To determine dissociation constant of a weak monobasic acid (CH_3COOH) by titrating against standard 0.1N NaOH using pH meter.	**4**
	7. To study the adsorption of oxalic acid by charcoal and verifying Freundlich adsorption isotherm.	**4**
	8. To detect the ultralow concentration of Cu^{2+} ions by silver colloids using colloid destabilization method.	**4**
Pedagogy	Students should be given suitable explanation revising the theoretical aspects prior to the conduct of each experiment. Pre and post laboratory assignments to be given. Each student performs the experiment individually.	
References / Readings, References for practicals	1. W. Rajbhoj, T.K. Chondhekar, Anjali Publication, Systematic experimental Physical Chemistry, 2000, Aurangabad, 2nd edition. 2. P.S. Sindhu, Practicals in Physical Chemistry, Macmillan India Publication, 2006, New Delhi, 1st edition. 3. B. Viswanathan, P.S Raghavan, Practical Physical Chemistry, Viva Books Private Ltd, Mumbai, 2005. 4. B. D. Khosla,; Garg, V. C. & A. Gulati, Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi, 18th Edition, 2018 5. P. S. Farinas, A. L. Doimo, A. R. da Silva, and I. F. Teixeira,	

	Synthesis and Application of Ag Nanoparticles for an Undergraduate Laboratory: Ultrasensitive Method to Detect Copper (II) Ions, J. Chem. Educ. 2020, 97, 10, 3771–3777
Course Outcome:	At the end of the course, students will be able to: 1. select catalysts for industrial and environmental applications. 2. predict the colloidal systems for surfactant industry. 3. differentiate efficiencies of various energy sources. 4. distinguish between different halides based on their solubility. 5. determine pH of various solution using different electrodes. 6. distinguish the type of colloid formed.

ATMANIRBHAR BHARAT
SWAYAMPURNA GOA

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(Accredited by NAAC)

GU/Acad –PG/BoS -NEP/2024/100 Date: 16.05.2024

Ref: GU/Acad –PG/BoS -NEP/2023/102/8 dated 15.06.2023

CIRCULAR

In supersession to the above referred Circular, the Syllabus of Semester III to VIII of the **Bachelor of Science in Microbiology** Programme approved by the Standing Committee of the Academic Council in its meeting held on 06th, 07th and 21st March 2024 is enclosed. The syllabus of Semester I and II approved earlier is also enclosed.

The Dean/ Vice-Deans of the School of Biological Sciences and Biotechnology and Principals of the Affiliated Colleges offering the **Bachelor of Science in Microbiology** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2024.05.16 10:46:31 +05'30'

(Ashwin Lawande)
Assistant Registrar – Academic-PG

To,

The Principals of Affiliated Colleges offering the Bachelor of Science in Microbiology Programme.

Copy to:

1. The Director, Directorate of Higher Education, Govt. of Goa
2. The Dean, School of Biological Sciences and Biotechnology, Goa University.
3. The Vice-Deans, School of Biological Sciences and Biotechnology, Goa University.
4. The Chairperson, BOS in Microbiology.
5. The Controller of Examinations, Goa University.
6. The Assistant Registrar, UG Examinations, Goa University.
7. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

V	MIC-300 Industrial Microbiology (4) MIC-301 Virology (4) MIC-302 Mycology and Protista (4) MIC-303 Introduction to Bioinformatics (2)	MIC-321 Medical Microbiology (4)			MIC-361 Internship (2)			20	

VI	MIC-304 Agricultural Microbiology (4) MIC-305 Immunology (4) MIC-306 Taxonomy and Systematics of Prokaryotes (4) MIC- 307 Project (4)	MIC- 322 Food Microbiology (4)					20	
VII*	*# MIC-400 Research Methodology (4) #MIC-401 Haematology and Clinical Biochemistry (4)	MIC-411 Waste Management and Bioremediation (4)					20	

SEMESTER V

Name of the Programme : B.Sc. Microbiology
Course Code : MIC-300
Title of the Course : Industrial Microbiology
Number of Credits : Theory - 3, Practical - 1
Effective from AY : 2024-25

Prerequisites for the Course	Basic knowledge of microbial cell types, biochemistry, metabolism and physiology.	
Objectives	1. To gain proficiency about the fundamental principles of Industrial microbiology including microbial diversity, physiology and metabolism 2. To examine the role of microorganisms in various industrial processes such as fermentation 3. To develop practical skills in laboratory techniques relevant to industrial microbiology, including microbial isolation, cultivation and strain improvement 4. To explore significance of industrially important microorganisms and their metabolites. 5. To understand fermentation processes and product recovery.	
Content		**No. of Hours**
1	**Unit - 1**	**(15)**
A	Sources of industrially important microbes, Methods for their isolation. Primary screening- for production of antibiotic , enzyme, organic acid, vitamin, breakdown of organic volatile compounds. Secondary screening, Preservation and maintenance of industrial strains, Strain improvement and development.	**7**
B	Chemically defined medium vs complex medium, Fermentation media and raw materials- Carbon sources, Nitrogen sources, Minerals, Vitamins and growth factors, Precursors, Inducers and elicitors, Inhibitors, Antifoams. Media sterilization and methods	**7**
C	Inoculum buildup	**1**
2	**Unit - 2**	**(15)**
A	Types of bioreactors-Pilot-scale and production fermenters, Components of a typical bio-reactor, Constantly stirred tank and air-lift fermenters.	**5**
B	Types of fermentations: Aseptic and non-aseptic fermentations. Solid-state and liquid-state (stationary and submerged) fermentations, Batch, fed-batch and continuous fermentations. Monitoring and control of fermentation parameters - pH, temperature, dissolved oxygen, foaming and aeration.	**10**
3	**Unit - 3**	**(15)**
A.	Cell separation methods: Sedimentation, Filtration, centrifugation; Methods of Cell disruption:- Physical, Chemical, Enzymatic; Methods of product concentration: solvent extraction, precipitation, lyophilisation; Methods of product purification: Gel filtration, Ion exchange chromatography	**7**
B	Microbial productions (micro-organisms involved, media, fermentation conditions, downstream processing and uses) Citric acid, Penicillin, Vitamin B_{12}, Amylase	**8**
4	**Unit - 4 Practical**	**(30)**
1	Isolation and Screening of Antibiotic producers- Crowded plate method,	**6**

	Giant Colony technique	
2	Study of different parts of fermenter	**2**
3	Methods of Cell disruption and separation - sonication, centrifugation, sedimentation	**4**
4	Microbial fermentations for the production, downstream processing, and estimation of: (a) Enzymes: Amylase (b) Organic acid: Citric acid (d) Antibiotic: Penicillin	**10**
5	Bioassay of Penicillin	**4**
6	Bioassay of Vitamin B_{12}	**4**
Pedagogy:	Lectures/tutorials/assignments/Demonstration/Laboratory Experiments	
References/ Reading	1. Casida LE. (1991). Industrial Microbiology. 1st edition. Wiley Eastern Limited. 2. Crueger W and Crueger A. (2000). Biotechnology: A textbook of Industrial Microbiology. 2nd edition. Panima Publishing Co. New Delhi. 3. Glaze A.N. and Nikaido H. (2007). Microbial Biotechnology: Fundamentals of Applied Microbiology. 1st edition. W.H. Freeman and Company. 4. Okafor N. (2007) Modern Industrial Microbiology and Biotechnology. 1st Edition. Bios ScientificPublishers Limited. USA. 5. Patel AH. (1996). Industrial Microbiology .1st Edition. MacMillan India Limited Publishing Company Ltd. New Delhi, India. 6. Stanbury PF, Whitaker A and Hall SJ. (2006). Principles of Fermentation Technology. 2nd edition, Elsevier Science Ltd. 7. Waites M.J., Morgan N.L., Rockey J.S. and Higton G. (2001). Industrial Microbiology: An Introduction. 1st edition. Wiley – Blackwell. E-books / Journals	
Course outcome	1. Gained proficiency about the fundamental principles of Industrial microbiology including microbial diversity, physiology and metabolism 2. Examined the role of microorganisms in various industrial processes such as fermentation 3. Developed practical skills in laboratory techniques relevant to industrial microbiology , including microbial isolation , cultivation and strain improvement 4. Explored significance of industrially important microorganisms and their metabolites. 5. Understood fermentation processes and product recovery.	

Name of the Programme : **B.Sc. Microbiology**
Course Code : **MIC-301**
Title of the Course : **VIROLOGY**
Number of Credits : **Theory - 3, Practical - 1**
Effective from AY : **2024-25**

Prerequisites for the Course	Basic understanding of human physiology and genetics	
Objectives	1. To develop a comprehension of viral nature and properties. 2. To analyse the relationship between viruses and human health 3. To apply knowledge of viruses in molecular biology, therapy and agriculture. 4. To identify viruses, their vectors, cytopathic effects caused by them as well as learn preventive and control measures.	
Content		**No. of Hours**
1	**Unit - 1 Nature and Properties of Viruses**	**(15)**
A	Introduction: Discovery of viruses, nature and definition of viruses, general properties, concept of viroids, virusoids, satellite viruses and Prions, Structure of Viruses: Capsid symmetry, enveloped and non- enveloped viruses, Isolation, purification and cultivation of viruses.	**5**
B	Viral taxonomy: Molecular classification and nomenclature of different groups of viruses; Bacteriophages: Classification of bacteriophage on the basis of structure, One step multiplication curve	**5**
C	Bacteriophages: Lytic and lysogenic phages (lambda phage), concept of early and late proteins, Gene regulation in lambda phage	**5**
2	**Unit - 2 Viruses and Health**	**(15)**
A	Introduction to oncogenic viruses, Types of DNA and RNA oncogenic viruses: Different avian, animal and human oncogenic viruses (Tabulation), Role of oncogenic viruses in cancer biology, cell transformation, proto- oncogene, oncogene and tumour suppressor genes, metastasis	**5**
B	Emerging viruses causing disease: Zika, Nipah, Coronavirus; Viral Infection control by aseptic techniques, cleaning, physical agents and disinfection, protective clothing, isolation, Antiviral compounds and their mode of action, Interferon and their mode of action	**5**
C	General principles of viral vaccination, Definition and examples of types of viral vaccines - Classical vaccines (live attenuated, inactivated, and killed) and Modern vaccines (recombinant DNA and protein-based vaccines, Peptide vaccines, conjugate vaccines, RNA Vaccines, Hybrid vaccine, oncovirus vaccines)	**5**
3	**Unit - 3 Applied Virology**	**(15)**
A	Viruses as tools for vaccine development: Phases of vaccine trials, product management, data collection and management, outreach and awareness, viral vaccination schedule (tabulation)	**5**
B	Viruses as tools for molecular biology: using viruses to understand DNA replication, transcription, translation, protein formation and basics of immunology; viral genes/sequences for construction of gene vectors	**5**
C	Viruses in therapy: Viruses as vectors in gene therapy, Bacteriophages for phage therapy, Viruses in agriculture: Viruses as biocontrol agents/ biopesticides, Production of virus resistant/tolerant crops	**5**
4	**Unit - 4 Practicals**	**(30)**
1.	Study of the structure of important animal viruses (Rhabdo, influenza,	**4**

	hepatitis B, retroviruses and coronaviruses) using electron micrographs	
2.	Study of the structure of important plant viruses (Caulimo, Gemini, tobacco mosaic virus) using electron micrographs.	**4**
3.	Study of the structure of important bacterial viruses (T4, λ) using electron micrographs.	**2**
4.	Determination of phage titre from water/sewage sample.	**8**
5.	Study of cytopathic effects of viruses using photographs.	**2**
6.	Study of preventive and control measures of tumour causing viruses using pictures and diagrams (Human Papilloma Virus)	**2**
7.	Study and Identification of local insect vectors through pictures	**2**
8.	Local field surveys of viral outbreak/visit to local research stations / sericulture/poultry, fish, and prawn farms and submitting a report.	**6**
Pedagogy:	Lectures/tutorials/assignments/Demonstration/Surveys/field trips/Laboratory Experiments	
References/ Reading	1. Carter J and Saunders V. (2009), Virology: Principles and Applications. 2nd edition, John Wiley and Sons. 2. Dimmock, NJ, Easton, AL, Leppard, KN. (2016) Introduction to Modern Virology. 7th edition, Wiley-Blackwell Publishing Ltd. 3. Flint SJ, Enquist, LW, Krug, RM, Racaniello, VR, Skalka, AM. (2000) Principles of Virology, Molecular biology, Pathogenesis and Control. ASM press Washington DC. 4. Khare R. (2019) Guide to Clinical and Diagnostic Virology (2019), (ASM Books) 1st Edition, ASM Press 5. Levy JA, Conrat HF, Owens RA. (1994) Virology. 3rd edition, Prentice Hall publication, New Jersey. 6. Marmorosch K and Koprowski H. (1998) Methods in Virology,Vol. I and II. Academic Press. 7. Newman TB, KohnMA (2020) Evidence-Based Diagnosis: An Introduction to Clinical Epidemiology 2nd Edition, Cambridge University Press. 8. Ryan F (2020) Virusphere: From Common Colds to Ebola Epidemics--Why We Need the Viruses That Plague Us. 1st edition, Prometheus. 9. Wagner EK, Hewlett MJ. (2007), Basic Virology. 3rd edition, Blackwell Publishing 10. Zimmer C. (2015), A Planet of Viruses: (2015) 2nd edition, University of Chicago Press.	
Course Outcome	Student will be able to 1. Understand Viral Nature and Properties. 2. Analyse the relationship between viruses and human health 3. Apply knowledge of viruses in molecular biology, therapy and agriculture. 4. Identify viruses, their vectors, cytopathic effects caused by them as well as learn preventive and control measures	

Name of the Programme : **B.Sc. Microbiology**
Course Code : **MIC- 302**
Title of the Course : **MYCOLOGY AND PROTISTA**
Number of Credits : **Theory - 3, Practical - 1**
Effective from AY : **2024-25**

Prerequisites for the Course	Understand key concepts of living organisms	
Objectives	This course deals with: 1. To develop a solid understanding of microbiological concept of mycology spanning fungal morphology, taxonomy, and physiology 2. To develop a solid understanding of microbiological concept of Protists spanning their morphology, taxonomy, and physiology 3. To understand the ecological roles and significance of fungi 4. To understand the Algal diversity, their adaptation and economic importance	
Content		**No. of Hours**
1	**Unit -1 Mycology**	**(15)**
A	**Introduction to Mycology:** General characters and phylogeny of the kingdom Fungi, the concept of anamorph and teleomorph, fungal structure and reproduction	**4**
B	**Salient features of the following phylla** a) Chytridiomycota - Ex: *Allomyces* b) Zygomycota – Ex: *Rhizopus* c) Glomeromycota – Ex: *Glomus* d) Ascomycota - Ex: *Aspergillus* e) Basidiomycota - Ex: *Agaricus*	**5**
C	**Fungal Physiology & Ecology:** Fungal nutrition and growth, Fungal interaction with other organisms: pathogenesis (1 example of plant and humans), symbiotic associations (Mycorrhiza, Lichen)	**4**
D	**Applied Mycology:** Economic importance of fungi: medicine, industries, agriculture, bioremediation	**2**
2	**Unit -2 PROTISTA- Protozoa**	**(15)**
A	**Introduction to protozoology :** Characteristics of protozoa, cell structure and function, life cycles and reproduction	**4**
B	**Taxonomy and Classification of Protozoa** Classification based on morphology and molecular data, diagnostic features and identification, ecological roles and importance Fungi-Like Protists (Slime Moulds) Animal-Like Protists - *Trypanosoma* Amoeboid Protozoans- *Entamoeba histolytica* Flagellated Protozoans-*Leishmania* spp. Ciliated Protozoans-*Paramecium* Sporozoans-*Plasmodium* spp.	**8**
C	**Economic Importance of protozoa** Applications of protozoa in various fields, symbiotic relationships between protozoa and other organisms, protozoan diseases in humans (malaria, amoebiasis)	**3**
3	**Unit - 3 PROTISTA- Algae**	**(15)**
A	**Introduction to Phycology**	**4**

	Characteristics of algae, cell structure and function, life cycles and reproduction	
B	**Taxonomy and Classification of Algae** Classification based on morphology and molecular data, diagnostic features and identification, ecological roles and importance Chlorophycophyta (Green algae) Rhodophycophyta (Red algae) Phaeophycophyta (Brown algae) Chrysophycophyta (Golden-brown algae) Pyrrophycophyta (Dinoflagellates) Euglenophycophyta (Euglenoids) Xanthophycophyta (Yellow green algae) Bacillariophycophyta (Diatoms) Cryptophycophyta (Cryptomonads)	**8**
C	**Economic Importance of Algae** Applications of Algae in various fields, symbiotic relationships between Algae and other organisms, Algal diseases in humans.	**3**
4	**Unit - 4 Practical**	**(30)**
1.	Isolation of fungi from soil	**4**
2.	Microscopic examination of fungal morphology & staining techniques	**4**
3.	Demonstration of methods for quantifying fungal growth	**4**
4.	Production and estimation of enzyme by fungi	**4**
5	Determination of growth requirements for fungi: temperature, pH, nutrients	**4**
6	Preparation and study of algal culture (eg: euglenoids/diatoms)	**4**
7	Study of permanent slides of protozoan parasites	**2**
8	Microscopical examination of blood smears for protozoan parasites	**4**
Pedagogy:	Lectures/tutorials/assignments/Laboratory Experiments/Demonstration	
References/ Reading	1. Alexopoulus, C.J., Mims, C.W. and Blackwell, M., (2007) Introductory Mycology, John Wiley & Sons (Asia) Pvt. Ltd. 2. Arderson D.R. (1988) Comparative Protozology, Cambridge Uni. Press. 3. Chatterjee KD (2019) Parasitology Protozoology And Helminthology 13Ed, CBS 4. Cooke, R. C. and Whipps, J. M., (1993) Ecophysiology of fungi, Blackwell Scientific Publications, Oxford. 5. Davis, B. D., Dulbecco, R., Eisen, H. N. and Ginsberg, H. S., (1980) Microbiology, Harper and Row. 6. Deacon, J. W., (2022) Introduction to Modern Mycology, Volume 7 of Basic Microbiology, Blackwell Scientific Publications. 7. Domsch, K. H., Gams, W. and Anderson, T-H., (2008) Compendium of Soil Fungi, IHW-Verlag. 8. Gilman, J. C. and Joseph, C., (2015) A Manual of Soil Fungi, Daya Books. Grell, K.G. (1973) Protozoology, Springer Verlag 9. Kendrick, B., (2017) The Fifth Kingdom, Focus Publishers. 10. Markell, EK, John, DT, Krotoski WA (1999) Markell and Voge's Medical Parasitology, 8th ed, WB Saunders Co, . 11. Mehrotra, R. S. and Aneja, K. R., (2015) An Introduction to Mycology, Wiley Eastern Limited 12. Onions, A. H. S., Allsop, D. and Eggins, M. O. W., (2007) Smith's Introduction to Industrial Mycology, Edward Arnold, London.	
Course	Students will be able to:	

outcome	1. Demonstrate proficiency in analysing fungal morphology and physiology 2. Classify protists based on morphological and molecular characteristics 3. Describe algal diversity and adaptations using taxonomic keys 4. Apply practical skills in microscopy, culture techniques and taxonomic identification of fungi, protist and algae

Name of the Programme : **B.Sc. Microbiology**
Course Code : **MIC 303**
Title of the Course : **INTRODUCTION TO BIOINFORMATICS**
Number of Credits : **Theory - 2**
Effective from AY : **2024-2025**

Prerequisites for the Course	Computer knowledge and basics of biomolecules	
Objective:	The students will be able to 1. Understand concepts in bioinformatics 2. Understand the different tools for data analysis and representation 3. Apply the appropriate tool for processing of biological data 4. Analysis and interpret the biological data	
Content:		**No. of Hours**
1	**Unit - 1**	**(15)**
A	**Introduction to Bioinformatics:** Definition and understanding of bioinformatics as an interdisciplinary science; Scope of bioinformatics in modern life science research; Overview of concepts that form the basis of bioinformatics: The central dogma, concept of homology, molecular understanding of evolution	**5**
B	**Biological Databases:** meaning and types (primary and secondary databases); Types of biological database for Nucleotide sequence (GenBank, EMBL), Genomes (NCBI Genome, Ensembl), Protein sequence (SwissProt), Protein structure and function (PDB, KEGG). File formats (FASTA, FASTQ, PDB, GFF)	**5**
C	**Sequence alignments:** why does sequence alignment matter?; Evolutionary basis of sequence alignment; Local and Global Sequence alignment; Pairwise and multiple sequence alignment; Scoring an alignment; Scoring matrices (PAM, BLOSUM) and gap penalties	**5**
2	**Unit - 2**	**(15)**
A	**Basic bioinformatics tools:** Retrieval of Information from BLAST; understanding of BLAST; meaning of parameters including statistical scores; Multiple Sequence Alignment by Clustal W; Use of BioEdit for nucleotide sequence editing and alignment	**5**
B	**Phylogeny and Phylogenetic trees:** Introduction to phylogeny and applications of phylogenetic analysis; meaning of Terminologies used; Forms of tree representation (cladogram, phylogram); Methods for tree building (UPGMA, NJ); Generation of phylogenetic trees in MEGA	**5**
C	**Applications of Bioinformatics:** Introductory concepts in the following applications: Whole genome and metagenome analysis and annotation, Proteomics, Protein structure prediction and Molecular docking	**5**
Pedagogy:	Lectures/tutorials/assignments/Practical on computer/Demonstration	
References/ Readings	1. Baxevanis, Andreas D., Gary D. Bader, and David S. Wishart, eds. (2020) *Bioinformatics*. John Wiley & Sons. 2. Christensen H, (2018) Introduction to Bioinformatics in Microbiology, Springer Nature 3. Primrose, S.B., Twyman, R.M. (2006) Principles of Gene Manipulation. Wiley-Blackwell. 4. Ramsden, Jeremy. (2023) *Bioinformatics: an introduction*. 5. Springer Nature Rastogi S.C., Mendiratta N. and Rastogi P. (2013) Bioinformatics: methods and applications, genomics, proteomics and drug	

	discovery, Prentice Hall India Publication
Course Outcomes	The students 1. understand the different tools for data analysis 2. applies the appropriate tool for biological data processing 3. analyses the biological data 4. interprets the biological data

SEMESTER VI

Name of the Programme : B.Sc. Microbiology
Course Code : MIC-304
Title of the Course : Agricultural Microbiology
Number of Credits : Theory - 3, Practical - 1
Effective from AY : 2024-25

Prerequisites for the Course	Knowledge of basic structure and biology of bacteria, viruses and fungi. Understanding of key concepts in plant growth and development	
Objectives	1. To study the different types of microorganisms present in soil and understand their role in soil fertility. 2. To investigate the relationships between plants and microorganisms and examine their impact on plant growth. 3. To explore the role of Plant growth promoting bacteria in enhancing soil fertility and plant growth. 4. To learn about microbes as agents of plant diseases and examine strategies for its control. 5. To formulate biofertilizers and analyse plant response.	
Content		**No. of Hours**
1	**Unit - 1 Organic matter decomposition and Plant Microbe interactions**	**(15)**
A	Organic matter decomposition by microorganisms– humus formation, Rhizosphere and endophytic microflora and their role, R:S ratio, Microbivory	**5**
B	Plant diseases:Mode of entry of pathogens, disease symptoms of Bacterial diseases- Crown gall, Citrus cancer	**2**
C	Mode of entry of pathogens, disease symptoms of Viral diseases, viroids- TMV, Tomato leaf curl	**2**
D	Mode of entry of pathogens, disease symptoms of Fungal diseases- Loose smut of wheat - Ustilago nuda, Wilt - Fusarium	**2**
E	Control of plant diseases: cultural practices, chemical methods, biological methods	**4**
2	**Unit - 2 Phytostimulation and Bioinsecticides**	**(15)**
A	Phytostimulation by Plant Growth Promoting Bacteria (PGPB), Effect of PGPB on plants :Direct (Nitrogen fixation, Phosphate solubilisation and Potassium mobilization, IAA producers, ammonia producers, and Indirect (Siderophores, HCN)	**7**
B	Biopesticides (mode of action, factors influencing their action and target pests) - Introduction, types: bacterial- Bacillus thuringiensis, viral - NPV, fungal - Trichoderma	**8**
3	**Unit - 3 Biofertilizers and beneficial associations**	**(15)**
A	Biofertilizers – definition, importance and types i) Nitrogen fixing – Azotobacter, Rhizobium, (Nitrogenase, Nodulation, Hydrogenase), Azolla, Cyanobacteria ii) Phosphate solubilizing Microorganisms. iii) Vesicular Arbuscular Mycorrhiza (VAM), Types- ecto/endo, mechanism of symbiosis	**6**
B	Biochemistry of symbiotic and non- symbiotic nitrogen fixation	**4**
C	Application methods Steps in mass production of bacterial biofertilizers, Methods of	**5**

	preparation and application – liquid and carrier based, Mass production of blue green algae, Azolla and mycorrhiza.	
5	**Unit - 5 Practical**	**(30)**
1	Study of soil profiles from different locations	**4**
2	Study of microflora of different types of soils	**4**
3	solation of plant growth promoting bacteria: (a) Isolation of symbiotic nitrogen fixers (b) Isolation of non-symbiotic nitrogen fixers (c) Isolation of PSB (d) Isolation of KSB (e) Isolation of IAA producers (f) Isolation of siderophore producers	**12**
4	Formulation of biofertilizers : Liquid based biofertiliser, Carrier - based	**4**
5	Effect of biofertilizers on seedlings of Vigna radiata.	**6**
Pedagogy:	Lectures/tutorials/assignments/Demonstration/Laboratory Experiments	
References/ Reading	1. Agrios GN. (2004) Plant Pathology . 5th Edition. San Diego, Academic press. 2. Altman A (1997) Agriculture Biotechnology, 1st Edition Marcel decker Inc. 3. Atlas RM and Bartha R. (1998) Microbial Ecology: Fundamentals & Applications. 4th edition. USA. Benjamin/Cummings Science Publishing. 4. Barton LL & Northup DE Microbial Ecology. (2011) 1st Edition. Wiley Blackwell.USA 5. Campbell RE. Microbial Ecology. (1983) Blackwell Scientific Publication, 2nd edition. Oxford, England 6. Coyne MS. (1999) Soil Microbiology: An Exploratory Approach. Delmar Thomson Learning. 7. Glick B.R.(2020) Beneficial Plant Bacterial Interactions, 2nd Edition Springer 8. Glick BR, Pasternak JJ, and Patten CL. (2010). Molecular Biotechnology. 4th Edition. ASM Press 9. Mahendra K. Rai (2006) Hand Book of Microbial Biofertilizers, 1st Edition The Haworth Press, Inc. New York 10. Maier RM, Pepper IL and Gerba CP. (2009) Environmental Microbiology. 2nd edition. Academic Press 11. Rangaswamy G. (1998) Diseases of crop plants in India 1st Edition 12. Reddy, S.M. et al. (2001) Bioinoculants for Sustainable Agriculture and Forestry, 1st Edition Scientific Publishers 13. Saleem F and Shakoori AR. (2012) Development of Bioinsecticide, 1st edition Lap Lambert Academic Publishing. 14. Singh RS. (2005) Plant Diseases Management. 8th Edition. New Delhi. Oxford & IBH. E-books / Journals.	
Course outcome	1. Studied the different types of microorganisms present in soil and understood their role in soil fertility. 2. Investigated the relationships between plants and microorganisms and examined their impact on plant growth. 3. Explored the role of plant growth promoting bacteria in enhancing soil fertility and plant growth. 4. Learnt about microbes as agents of plant diseases and examined strategies for its control. 5. Formulated biofertilizers and analysed plant response.	

Name of the Programme : **B.Sc. Microbiology**
Course Code : **MIC-305**
Title of the Course : **IMMUNOLOGY**
Number of Credits : **Theory - 3, Practical - 1**
Effective from AY : **2024-25**

Prerequisites for the Course	Should know basics of microbiology and human anatomy and physiology	
Objectives	1. To understand the basics of human immune system and tolerance 2. To familiarize them with the contributions of Nobel laureates in Immunology 3. To illustrate various components of immune response 4. To appraise and distinguish the significance of normal and abnormal immune responses	
Content		**No. of Hours**
1	**Unit - 1 Introduction to Immunology**	**(15)**
A	Innate and Adaptive immunity; Tolerance and Autoimmune disorders (Tabular column); Contributions of - Edward Jenner, Robert Koch, Paul Ehrlich, Elie Metchnikoff, Peter Medawar, Macfarlane Burnet, Neils Jerne, Rodney Porter and Susumu Tonegawa, Georges Kohler and Cesar Milstein.	**5**
B	Structure, function and properties of Immune cells- Stem cells, B and T lymphocytes, NK cell, Macrophage, Neutrophil, Eosinophil, Basophil, Dendritic cell, and Mast cell	**5**
C	Structure and function of Immune organs- Bone marrow, Thymus, Lymph node, Spleen, MALT and GALT	**5**
2	**Unit - 2 Antigens and Antibodies and Major Histocompatibility Complex**	**(15)**
A	Characteristics of an Antigen (Foreignness, Molecular size and Heterogeneity); Haptens; B and T cell epitopes T-dependent and T-independent Antigens, Adjuvants	**5**
B	Structure, types, functions and properties of Antibodies Idiotypic, Isotypic and Allotypic determinants; Monoclonal Ab	**5**
C	Structure and function of MHC I and II; Cytosolic and Endocytic Pathways	**5**
3	**Unit - 3 Generation of Immune Response and Complement System and Hypersensitivity**	**(15)**
A	Primary and Secondary immune response; Generation of Humoral immune response - Plasma and Memory cells; Cell mediated immune response- Self MHC restriction	**5**
B	Components of the Complement system- Classical, Alternative and Lectin Pathways and their regulation	**5**
C	Hypersensitivity I, II, III, IV, V	**5**
4	**Unit - 4 Practical**	**(30)**
1.	Demonstration of Neubauer's Counting chamber	**2**
2.	Differential Leucocyte Count	**4**
3.	Immunological Techniques- Study of precipitation -VDRL	**6**
4.	Study of Hemagglutination- Blood grouping, WIDAL	**6**
5.	Demonstration of Immunoelectrophoresis	**4**
6.	Demonstration of Immunodiffusion by Ouchterlony method	**2**

7.	Preparation of serum	**2**
8.	Paper electrophoresis of serum proteins	**4**
Pedagogy:	Lectures/tutorials/assignments/Demonstration/Laboratory Experiments	
References/ Reading	1. Coico R., Geoffrey S., (2009) Immunology. 6th Edition. Wiley- Blackwell. 2. Delves P.J., Martin S.J., Burton D.R,, Roitt I.M. (2017) Roitt's Essential Immunology. 13th Edition. Wiley- Blackwell. 3. Kindt T.J., Goldsby R.A., Osborne B.A. (2006) Kuby's Immunology. 6th Edition. W.H. Freeman and Company. 4. Murphy K., Travers P., Walport M. (2011) Janeway's Immunobiology. 8th Edition. Garland Science. 5. Peakman M. and Vergani D. (2009) Basic and Clinical Immunology. 2nd Edition. Churchill Livingstone.	
Course outcome	Students would have 1. Perceived the overview of human immune system 2. Explained the structure and functions of immune cells and organs 3. Understood the concepts of antigens and antibodies and MHC and their correlation 4. Comprehended the mechanisms of Immune response and Complement system 5. The ability to compare and contrast between various Hypersensitivity reactions 6. Designed the experiments to demonstrate immunological reactions and gained hands on experience in Immuno-techniques	

Name of the Programme : **B.Sc. Microbiology**
Course Code : **MIC-306**
Title of the Course : **TAXONOMY AND SYSTEMATICS AND PROKARYOTES**
Number of Credits : **Theory - 3, Practical – 1**
Effective from AY : **2024-25**

Prerequisites for the Course	It is assumed that students should have a basic understanding of binomial nomenclature, the basis of classification systems and be familiar with the distinguishing features of different groups of microorganisms.	
Objectives	1.To impart the concepts of microbial taxonomy and systematics 2.To understand the rules governing the different taxonomy and classification systems 3.To explain the salient features of different microbial groups 4.To develop the competency of identifying prokaryotes	
Content		**No. of Hours**
1	**Unit - 1**	**(15)**
A	**Microbial Taxonomy and Systematics** Major characteristics used in classification, Microbial taxonomy and systematics Concepts of taxonomy (characterization, classification and nomenclature) and systematics; classification of microorganisms, three domain, six-kingdom, 8-kingdom systems endosymbiotic theory	5
B	Phenotypic characters - Morphology, Biochemical tests (e.g. API, BIOLOG), Bacteriophage typing, Serotyping.	5
C	Chemotaxonomic markers - Cell wall components, lipid composition, cellular fatty acid (FAME analysis), isoprenoid quinones, protein profiles (e.g. MALDI-TOF)	5
2	**Unit - 2**	**(15)**
A	Nucleic acid based techniques – Terminal Restriction Fragment Length Polymorphism (TRFLP), G+C content (Tm and HPLC), pyrosequencing, 16S rRNA gene sequencing, phylogenetic analysis, DNA-DNA hybridization.	5
B	Concept of species, numerical taxonomy and polyphasic taxonomy.	5
C	Salient features of phylum, class and orders with representative examples of Archaea	5
3	**Unit - 3**	**(15)**
A	Salient features of phylum, class and orders with representative examples of Eubacteria (bacteria, cyanobacteria, actinomycetes)	5
B	Salient features of phylum, class and orders with representative examples of Mycota	5
C	Salient features of phylum, class and orders with representative examples of Protista (algae, protozoa, diatoms) and viruses.	5
4	**Unit - 4 Practicals**	**(30)**
1	Morphological, physiological and biochemical characterization of bacteria	**6**
2	Chemotaxonomic analysis of cell wall (sugars & amino acids)	**6**
3	Characterization of actinomycetes (*Streptomyces* sp.)	**4**
4	Identification of cyanobacteria	**4**
5.	Characterization of yeast (*Saccharomyces cerevisiae*).	**4**
6.	Characterization of fungi (*Penicillium, Rhizopus*)	**4**

7.	Demonstration of identification of bacteria using BLAST analysis	**2**
Pedagogy	Lectures / Tutorials / Assignments /Laboratory Experiments	
References / Readings	1. Barlow, A. (ed.), (1992) The prokaryotes: a handbook on the biology of bacteria: ecophysiology, isolation, identification, applications, Volume 1 Springer-Verlag. 2. Goodfellow, M. and Minnikin, D.E. (eds.), (1985) Chemical methods in bacterial systematics, The Society for Applied Bacteriology. Technical Series No. 20, Academic Press. 3. Goodfellow, M., Mordarski, M. and Williams, S. T. (eds.), (1984) The biology of the actinomycetes. 4. Kurtzman, C. P., Fell, J. W. and Boekhout, T. (eds.), (2011) The yeasts - a taxonomic study. 5. Norris, J. R. and Ribbons, D.W. (eds.), (1971) Methods in microbiology, Vol. 18 & 19. 6. Priest, F. G. and Austin, B. (1994). Modern bacterial taxonomy, Chapman and Hall. 7. Sneath, A. H. P., Mair, S. N. and Sharpe, E. M. (eds.), (1986) Bergey's manual of systematic bacteriology Vol. 2. Williams & Wilkins Bacteriology Symposium, Series No 2, Academic Press, London/New York.	
Course outcomes	The student will be able to 1. Apply knowledge of the standard rules of classification systems to categorize microorganisms. 2. Understand the distinguishing features of bacteria and archaea and the techniques of identification of prokaryotes 3. Appreciate and explain the dynamic and ever developing nature of the field of microbial taxonomy and systematics. 4. Explain the salient features of different microbial groups.	

ATMANIRBHAR BHARAT
SWAYAMPURNA GOA

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(Accredited by NAAC)

GU/Acad –PG/BoS -NEP/2024/97 Date: 15.05.2024

Ref: GU/Acad –PG/BoS -NEP/2023/102/7 dated 16.06.2023

CIRCULAR

In supersession to the above referred Circular, the updated approved Syllabus of the **Bachelor of Science in Botany** Programme approved by the Standing Committee of the Academic Council in its meeting held on 06th, 07th and 21st March 2024 is enclosed.

The Dean/ Vice-Deans of the School of Biological Sciences and Biotechnology and Principals of the Affiliated Colleges offering the **Bachelor of Science in Botany** Programme are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2024.05.15 14:30:46 +05'30'

(Ashwin Lawande)
Assistant Registrar – Academic-PG

To,

The Principals of Affiliated Colleges offering the Bachelor of Science in Botany Programme.

Copy to:

1. The Director, Directorate of Higher Education, Govt. of Goa
2. The Dean, School of Biological Sciences and Biotechnology, Goa University.
3. The Vice-Deans, School of Biological Sciences and Biotechnology, Goa University.
4. The Chairperson, BOS in Botany.
5. The Controller of Examinations, Goa University.
6. The Assistant Registrar, UG Examinations, Goa University.
7. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

IV	BOT-202 #$& Anatomy and Reproductive Biology of Flowering Plants (3T+1P) BOT-203 #$& Cell Biology and Plant Biochemistry (3T+1P) BOT-204 @%* Biofertilizers (3T+1P) BOT-205 #$& Palynology (1T+1P)	BOT-221 Techniques in Floral Arrangement (2T+2P) [VET] OR BOT-222 Ecotourism (2T+2P) [VET]							BOT-261 Organic farming (1+3)
V	BOT-300 #$& Plant Taxonomy and Phylogeny (3T+1P) BOT-301 #$& Cytogenetics and Plant Breeding (3T+1P)	BOT-321 Mushroom Cultivation Technology (3T+1P) [VET]			BOT-361 Internship- (2)				

	BOT-302 @%* Microbiology and Plant Pathology (3T+1P) BOT-303 #$& Field Botany (1T+1P)									
VI	BOT-304 @%* Plant Tissue Culture (3T+1P) BOT-305 @%* Plant Ecology and Phytogeography (3T+1P) BOT-306 #$& Molecular Biology and Genetic Engineering (3T+1P) BOT-307 #$& Minor Project (4)	BOT-322 Post-harvest Technology of Fruits and Vegetables (3T+1P) [VET]							20	

Disciplinary/Interdisciplinary Minor

Name of the Programme : B. Sc. (Botany)
Course Code : BOT-321
Title of the Course : Mushroom Cultivation Technology
Number of Credits : 4 (3 Theory + 1 Practical)
Effective from AY : 2024-25

Prerequisites for the course:	Basic knowledge of biology of fungi.	
Course Objectives:	This course aims to: 1. Train students in basic mushroom cultivation techniques. 2. Impart knowledge of pest and disease management and post-harvest technology. 3. Upskill students for mushroom entrepreneurship and research.	
Content:	**Theory:**	**45 hours**
	Module 1: Biology of mushroom and mushroom cultivation **Mushroom biology:** Morphology, diagnostic characters, reproduction, life cycle and nutritional value of *Agaricus bisporus*, *Calocybe indica* and *Pleurotus* spp. Mushroom classification based on occurrence, habitat, colour and morphology of fruiting bodies. Important features of edible and non-edible mushrooms (common look-alike mushrooms). **Mushroom cultivation -** Cultivation of button, oyster and milky white mushrooms - spawning, casing, cropping, picking and packing. Mushroom spore isolation and spore culture; pileus tissue culture; culture media (Potato Dextrose Agar, Malt Extract Agar). Preparation of spawn and substrate, sterilization and storage. Infrastructure requirement of a mushroom firm - composting technology, pasteurization room and growing rooms.	**15 hours**
	Module 2: Pest and diseases management **Pest and diseases:** Cultivated mushroom diseases, pests and their management - Button mushroom- fungal diseases (dry bubble, wet bubble); weed fungi (olive green mould, brown plaster mould); bacterial diseases (brown blotch, ginger blotch). Oyster mushroom- fungal diseases (*Cladobotryum* soft rot, *Gliocladium* brown rot); bacterial (rot, yellow blotch). Milky white mushroom- fungal (wet bubble, dry bubble) bacterial (blotch). Pests (Spring tails and mites). **Disease management methods:** Purity of spawn mother culture, strain vigor and genetic characteristics, strain improvement, fumigation, improvement in compost sterilization procedures, quality assurance steps**.**	**15 hours**
	Module 3: Post-harvest technology, storage, economics and future of mushroom cultivation in Goa **Post-harvest technology:** Storage of fresh mushrooms (refrigeration, vacuum cooling, ice-bank cooling, irradiation), conventional packaging, Modified Atmosphere Packaging	**15 hours**

	(MAP), Controlled Atmosphere Packaging (CAP), Modified Humidity Packaging (MHP), labelling. Transportation of fresh mushrooms. Long term storage, innovative products (steeping, canning, pickles, drying, papad). **Economics in mushroom cultivation:** Study of model of a unit for cost for site, spawn production, compost unit, machinery for small scale farm. Cost benefit ratio. Marketing in India and abroad. Alternate business models (ready to grow beds, DIY kits). **Future of mushroom cultivation:** Advantages of using local species, strains for mushroom cultivation (*Calocybe indica* and *Schizophyllum commune*). Popular exotic mushrooms (*Volvariella volvacea*, *Lentinula edodes*). Strain improvement in *Agaricus bisporus*. Spent mushroom substrate as organic manure. Mushrooms cultivated for their medicinal importance (*Ganoderma*, *Cordyceps*). Mushroom research centre ICAR-DMR Directorate of Mushroom Research, Solan and summary of its work.	
	Practical:	**30 hours**
	1. Basidiocarp morphology of oyster mushroom; L.S. of basidiocarp, section through gill and mounting of spores.	**2 hours**
	2. Basidiocarp morphology of button mushroom; L.S. of basidiocarp, section through gill and mounting of spores.	**2 hours**
	3. Preparation and sterilization of media (Malt Extract Agar and Potato Dextrose Agar).	**4 hours**
	4. Initiation of culture from mushroom tissues and spores.	**2 hours**
	5. Preparation of spawn and substrate for oyster mushroom cultivation and milky white mushroom cultivation.	**6 hours**
	6. Inoculation and bagging of substrate using oyster mushroom spawn and milky white mushroom spawn.	**6 hours**
	7. Debagging, initiation of fruiting and harvesting of oyster mushrooms.	**2 hours**
	8. Casing, initiation of fruiting and harvesting of milky white mushrooms.	**2 hours**
	9. Mushroom preservation – drying, storage in brine and pickle making.	**2 hours**
	10. Packaging and marketing of fresh and dry mushroom products.	**2 hours**
Pedagogy:	Lectures, tutorials, assignments, presentations, demonstrations and team-based learning.	
References/ Readings:	1. **Atkinson**, **GF** (1961). Hand book of Mushrooms. 2nd edition. Hafner Publishers, New York. 2. **Bahl**, **N** (2000). Handbook of Mushrooms. 4th edition. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi. 3. **Biswas**, **S**, **Datta**, **M** and **Ngachan**, **SV** (2012). Mushrooms: A Manual for Cultivation. PHI Learning Private Limited, New Delhi.	

	4. **Chang**, **ST** and **Miles**, **PG** (2004). Mushrooms: Cultivation, Nutritional Value, Medicinal Effect and Environmental Impact. CRC Press Inc., USA. 5. **Dubey**, **RC** (1993). A Textbook of Biotechnology. S. Chand & Company Pvt. Ltd., New Delhi. 6. **Kannaiyan**, **S** and **Ramasamy**, **K** (1980). A handbook of Edible Mushroom. Today and Tomorrows Printers and Publishers, New Delhi. 7. **Marimuthu**, **T**, **Krishnamoorthy**, **AS**, **Sivaprakasam**, **K** and **Jayarajan**, **R** (1991). Oyster Mushrooms. Tamil Nadu Agricultural University, Coimbatore. 8. **NIIR Board** (2006). Handbook of Mushroom Cultivation, Processing and Packaging. National Institute of Industrial Research, New Delhi. 9. **Singh**, **M**, **Vijay**, **B**, **Kamal**, **S** and **Wakchaure**, **GC** (2011). Mushrooms: Cultivation, Marketing and Consumption. Directorate of Mushroom Research (ICAR), Solan. 10. **Stamets, P** and **Chilton, JS** (1983). The Mushroom Cultivator: A Practical Guide to Growing Mushrooms at Home. Agaricon Press, Washington D.C. 11. **Swaminathan**, **M** (1990). Food and Nutrition. The Bangalore Printing and Publishing Company Ltd., Bangalore. 12. **Tiwari**, **SC** and **Kapoor**, **P** (1988). Mushroom cultivation. Mittal Publications, New Delhi. 13. **Tripathi**, **DP** (2005). Mushroom Cultivation. Oxford and IBH Publishing Company Pvt. Ltd., New Delhi. https://dmrsolan.icar.gov.in/Mushroom_Cultivation_Marketing_Consumption.pdf https://dmrsolan.icar.gov.in/html/leafletsfolders.html
Course Outcomes:	On completion of this course, students will be able to: 1. Identify important cultivated edible mushroom species available in India. 2. Develop basic skills in spawn production, substrate preparation and mushroom cultivation. 3. Recognize and manage mushroom diseases and pests. 4. Create employment opportunities through mushroom cultivation and motivate them for research.

Disciplinary/Interdisciplinary Minor (VET)

Name of the Programme : B. Sc. (Botany)
Course Code : BOT-322
Title of the Course : Post-harvest Technology of Fruits and Vegetables
Number of Credits : 4 (3 Theory + 1 Practical)
Effective from AY : 2024-25

Prerequisites for the course:	Basic knowledge of Biology.	
Course Objectives:	This course aims to: 1. Provide an overview of the various harvesting, handling, storage, packaging and preservation techniques used for post-harvest processing of fruits and vegetables. 2. Impart practical skills in preparation of various value-added food products using fruits and vegetables.	
Content:	**Theory:**	**45 hours**
	Module1: Introduction to post-harvest technology, harvesting, handling and storage techniques **Introduction to post-harvest technology:** Definition, scope and importance; physiology and biochemistry of fruit ripening; textural changes seen in fruits and vegetables due to over-ripening; ethylene evolution and its management; factors influencing post-harvest quality (temperature and humidity). **Harvesting and handling practices:** Harvesting methods for different fruits and vegetables; influence of pre-harvest practices on post-harvest quality; handling practices to minimize damage; sorting, grading and packing techniques; field containers for collection; transport from field to storage area; treatment of fruits and vegetables (washing, sanitization, waxing and curing); pre-cooling methods; packaging and shipment methods. **Storage techniques:** Methods for storage (cold storage, controlled atmosphere storage and modified atmosphere packaging).	**15 hours**
	Module 2: Microbial spoilage and preservation techniques **Microbial spoilage:** Introduction, causes of spoilage of fruits and vegetables; identification and management of common diseases of fruits and vegetables; integrated pest management in post-harvest handling; quarantine measures and regulations. **Preservation techniques:** Principles of preservation (asepsis and removal of microorganisms); methods of preservation - chemical preservation (use of preservatives); physical preservation (irradiation, low temperature, heat treatment, dehydration); canning and bottling; aseptic packaging. **Quality maintenance:** Monitoring and control of environmental conditions; pest and disease management during storage; quality assessment techniques; quality standards and certifications; monitoring and controlling post-harvest losses.	**15 hours**

	Module 3: Post-harvest processing, value addition and management **Processing techniques:** Principles and scope of processing; methods of processing fruits and vegetables by freezing, dehydration, pickling, preservation using sugar and salt, canning and fermentation; preparation of value-added food products (juice, squash, jam, marmalade, sauce and ketchup); quality considerations in processing. Processing of plant and vegetable products: a. **Frozen vegetables -** Carrot (*Daucus carota*) and peas (*Pisum sativum*). b. **Dehydrated products** – Potato (*Solanum tuberosum*) chips and garlic (*Allium sativum*) powder. c. **Preparation of pickles** – Bitter gourd (*Momordica charantia*) and brinjal *(Solanum melongena)*. d. **Canned products** - Preparation of sugar syrup and canning of jackfruit (*Artocarpus heterophyllus*); preparation of brine and canning of green mango (*Mangifera indica*). e. **Fermented products** – Coconut (*Cocos nucifera*) vinegar and pineapple (*Ananas comosus*) wine. f. **Juices and squashes** - Kokum (*Garcinia indica*) juice and strawberry (*Fragaria* sp.) squash. g. **Jams and marmalades** - Guava (*Psidium guajava*) jam and orange (*Citrus sinensis*) marmalade. h. **Sauces and ketchups** - Chilli (*Capsicum annuum*) sauce and tomato (*Solanum lycopersicum*) ketchup. **Emerging technologies in post-harvest management**: Use of technology for quality control, automation in processing and packaging.	**15 hours**
	Practical:	**30 hours**
	1. Identification (botanical name and family) of fruits and vegetables (grapes, papaya, pineapple, orange, mango, kokum, tomato, lime, ginger, gooseberry and cucumber) used in preparation of value-added products.	**2 hours**
	2. Preparation and preservation of tomato ketchup (demonstration).	**2 hours**
	3. Preparation of raisins, tutti fruity and ginger/gooseberry candy (demonstration).	**4 hours**
	4. a. Demonstration of lime pickle/any suitable pickle. b. Demonstration of dill pickle of cucumber.	**2 hours**
	5. a. Demonstration of fermentation of coconut toddy or juice of any suitable fruit for production of vinegar. b. Determination of acetic acid content of vinegar.	**4 hours**
	6. Fermentation of fruit juice (pineapple/grapes or any suitable fruit) for preparation of wine and determination of alcohol content using a hydrometer/alcoholometer (demonstration).	**4 hours**

	7. Effect of heat on vitamin C content of packaged apple juice beverage.	**2 hours**
	8. Preparation of kokum syrup/ginger-lemon concentrate (demonstration).	**2 hours**
	9. Preparation of dried kokum rind/raw mango slices (demonstration).	**2 hours**
	10. Preparation of orange marmalade and mixed fruit jam (demonstration).	**4 hours**
	11. Study of different types of machinery, equipment and packaging materials used in processing/packaging of fruits and vegetables using photographs.	**2 hours**
Pedagogy:	Lectures, use of multimedia, assignments, presentations, hands-on experiments, demonstrations and team-based learning.	
References/ Readings:	1. **Ahiduzzaman**, **MD** (2022). Postharvest Technology: Recent Advances, New Perspectives and Applications. CBS Publishers & Distributors Pvt. Ltd., New Delhi. 2. **Ashraf**, **SM** (2008). Handbook of Fruit and Vegetable Products. Agrobios, India. 3. **Cruess**, **WV** (2004). Commercial Fruit and Vegetable Products. Agrobios, India. 4. **Dubey**, **RC** (1993). A Textbook of Biotechnology. S. Chand & Company Pvt. Ltd., New Delhi. 5. **Frazier**, **WC** and **Westhoff**, **DC** (2008). Food Microbiology. Tata McGraw Hill Education Private Limited, New Delhi. 6. **Kader**, **AA** (2002). Postharvest Technology of Horticultural Crops. University of California, Agriculture and Natural Resources, USA. 7. **Lal G**, **Siddappa**, **GS** and **Tandon**, **GL** (2019). Preservation of Fruits and Vegetables. ICAR, New Delhi. 8. **Manay**, **SN** and **Shadaksharaswamy**, **M** (2008). Foods: Facts and Principles. New Age International, Bengaluru. 9. **Narang**, **RK** (2010). Fruit and Vegetable Preservation Techniques. APH Publishing Corporation, Delhi. 10. **Potter**, **NN** and **Hotchkiss**, **HJ** (1996). Food Science. CBS Publishers & Distributors, New Delhi. 11. **Rahman**, **MS** (2020). Handbook of Food Preservation. 3rd edition. CRC-Press, United States. 12. **Ranganna**, **S** (1986). Handbook of Analysis and Quality Control for Fruits and Vegetable Products. 2nd edition. Tata McGraw-Hill Publishing Company Limited, New York. 13. **Saldanha**, **E** (2010). Successful Goan Home Wines. Rajhauns Vitaran, Goa. 14. **Sehgal**, **S** (2016). A Laboratory Manual of Food Analysis. I.K. International Publishing House Pvt. Ltd., New Delhi. 15. **Srilakshmi**, **B** (2007). Food Science. New Age International (P.) Limited, New Delhi. 16. **Srivastava**, **RP** and **Kumar**, **S** (2017). Fruit and Vegetable Preservation: Principles and Practices. 3rd edition. CBS Publishers	

	and Distributors Pvt. Ltd., India. 17. **Thompson**, **AK** (2003). Fruit and Vegetables: Harvesting, Handling and Storage. 2nd edition. Blackwell Publishing Ltd., U.S. 18. **Verma**, **LR** (2000). Post Harvest Technology of Fruits and Vegetables: Handling, Processing, Fermentation and Waste Management. Volume I & II. Indus Publishing Company, New Delhi. 19. **Wills**, **R**, **Golding**, **I** and **Graham**, **D** (2016). Postharvest: An Introduction to the Physiology and Handling of Fruit and Vegetables, 6th edition. Centre for Agriculture and Bioscience International, Cambridge. 20. **Wolff**, **IA** (1982). CRC Handbook of Processing and Utilization in Agriculture. Volume 1, Volume 2, Parts 1-2. CRC Press, California.
Course Outcomes:	On completion of this course, students will be able to: 1. Recall post-harvest processes and factors influencing post-harvest quality. 2. Identify microbial spoilage of fruits and vegetables and use effective methods for preservation and maintaining the quality of fruits and vegetables. 3. Utilize effective harvesting, handling and storage strategies for marketing of fruits and vegetables ensuring minimal post-harvest losses. 4. Develop skills in processing and preparation of different value-added products using fruits and vegetables.