Savitribai Phule Pune University

Pune, India

Faculty of Science and Technology

<u>Fourth year B.Sc. Blended Honors Program</u>

Subject: **Chemistry, Earth Science, Environment Science and Physics**

Structure and Syllabus of Fourth Year

B.Sc. Blended Honors Degree Program

Effective from Academic year 2026 – 2027

The present syllabus has been developed through a participatory and consultative process involving extensive discussions with faculty members from the different disciplines of Physics, Chemistry, Earth and Environmental Science along with a careful review of existing curricula and contemporary academic requirements. In accordance with the directives of the University Grants Commission (UGC) and the framework of the National Education Policy (NEP–2020), the curriculum for the undergraduate program has been designed to align with the objectives of multidisciplinary, outcome-based, and skill-oriented education.

Under the autonomous framework and in accordance with the revised guidelines issued by Savitribai Phule Pune University, the Interdisciplinary School of Science has designed the B.Sc. (Honors) syllabus from the academic year 2024-2025 onwards. The curriculum has been designed for review of the Board of Studies in the above subjects, keeping in view the contemporary relevance, emerging trends, and applications of various branches of physics, chemistry, earth and environmental science.

The process of curriculum design was initiated through a series of academic deliberations and orientation programs conducted to familiarize faculty members with the vision, principles, and implementation framework of NEP-2020. These discussions enabled effective incorporation of the key aspects of the policy, including flexibility, interdisciplinarity, experiential learning, research orientation, and outcome-based education into the revised curriculum structure.

The learning outcome-based curriculum for the B.Sc. (Blended) program is intended to provide students with a strong conceptual foundation in the above subjects while simultaneously developing analytical thinking, problem-solving abilities, experimental skills, and research aptitude. The curriculum is designed to prepare students for higher education, research, industry, and other professional opportunities in the field of science and technology.

While framing the syllabus, due consideration has been given to the UGC Learning Outcomes-based Curriculum Framework (LOCF), the recommendations of NEP–2020, and the model curriculum prescribed by Savitribai Phule Pune University to ensure academic quality, relevance, and alignment with national educational objectives

Structure of the Syllabus with Credit Framework for VII and VIII Semester (4th Year)

Level/ Difficulty	Sem	Major Core /DSC	Major Elective/DSE	Minor	GE/ OE	VS, SEC	AEC, VEC, IKS	FP/CEP/CES/ OJT/ RP/ CC	Total Credit	Degree/ Cum. Credit
Vertical (V)		V-1	V-1			V-3		V-5		
6.0 /400	VII	**CHE 401 MJ:** Advanced concepts in physical chemistry **CHE 402 MJ:** Modern spectroscopic methods in structure determination of organic compounds **CHE 403 MJ:** Chemistry of Macromolecules **GEO 401 MJ:** Applications of Mineralogy and Crystal Chemistry **GEO 402 MJ:** Petrological processes in Earth Sciences **GEO 403 MJ:** Geodynamics & Structural Evolution of the Earth **EVS 401 MJ:** Habitat and Wildlife: Conservation and Management **EVS 402 MJ:** EIA and Environmental Audit **EVS 403 MJ:** Fundamentals of Environmental Biology and Biodiversity **PHY 401 MJ:** Mathematical Methods in Physics **PHY402 MJ:** Computer Programming and Numerical Methods **PHY 403 MJ:** Instrumentation: Circuits & Electronics **4 Credit (T)**	**CHE 404 MN:** Modern concepts in molecular symmetry **CHE 405 MN:** Advanced industrial formulation chemistry **GEO 404 MN:** Gemmology & its application **GEO 405 MN:** Petroleum, Coal and Hydrocarbon systems **EVS 404 MN:** Atmosphere and Climate Change **EVS 405 MN:** Ecotoxicology and E-waste management **PHY 404 MN:** Basics of Density Functional Theory **PHY 405 MN:** Basics of Optoelectronics **2 Credit (T)**	**CHE/GEO/EVS/ PHY 406 RM:** Theory of research, research tools and methods **4 Credit (T)**	–	–	–		22	**UG Honours Degree 176**

		CHE/GEO/ EVS/PHY 407 MJ (P) RP/ FP/ Practical **2 Credit (T)**								
	VIII	**CHE 451 MJ**: Coordination and Bioinorganic chemistry **CHE 452 MJ**: Advanced synthetic organic chemistry **CHE 453 MJ**: Green chemistry and Its application **GEO 451 MJ:** Advanced Geochemistry **GEO 452 MJ:** Disaster Management **GEO 453 MJ:** Quaternary geology **EVS 451 MJ:** Sustainable Development Goals **EVS 452 MJ:** Disaster Management **EVS 453 MJ:** Environmental Pollution and its effects on human health **PHY 451 MJ:** Advance Quantum Mechanics **PHY452 MJ:** Physics of semiconductor Devices **PHY453 MJ:** Quantum Materials and Topological physics **4 Credit (T)** **CHE/GEO/ EVS/PHY 457 MJ (P)** RP/ FP/ Practical **2 Credit (T)**	**CHE 454 MN:** Analytical methods for material characterization. **CHE 455 MN**: Polymer Chemistry **GEO/EVS 454 MN:** Landscape Analyses and Remote sensing **GEO/EVS 455 MN:** Natural Resource Management **PHY 454 MN:** X ray crystallography **PHY 455 MN:** Rietveld Analysis **2 Credit (T)**	**–**	**–**	**–**	**–**	**CHE/GEO /EVS/PHY 432 RP/ FP:** Fieldwork/Industrial training/ Research Project **4 Credit (P)**	**22**	
Year 3	**VII+VIII**	**14 + 14**	**4 + 4**	**04 + 0**				**00 + 04**	**44**	
Students who successfully complete the four-year B.Sc. Blended (Honors) programme with a Major and Minor, earning a total of 176 credits										

Assessment and Evaluation

a) **<u>In-semester Assessment</u>**: The Departmental Internal Assessment Committee will coordinate this activity. Internal assessment for each course would be continuous and dates for each tutorials/practical tests will be pre-notified in a separate time table.

i) Theory Courses: There will be a minimum one test of 10 marks for each credit in a theory course comprising of 4 credits (i.e. 4 tests per course) and will compose multiple choice and or short answer questions. The marks for each test will be displayed on the notice board within a week of conducting the test. Of the total period of 15 weeks of teaching, the internal assessment tests will commence after 3 weeks and 2 to 4 tests will be conducted for 2 credit and 4 credit courses respectively. In addition, 10 marks oral examination will be conducted for each 4-credit theory course.

b) **<u>Term End Examination</u>**: The term end examination for 50 marks per course, would be held about two weeks after completion of teaching for the semester. Paper setting and assessment for a particular course would be the responsibility of the course In-charge. These activities would be co-ordinated by the Department Examination Committee chaired by the Head of Department. The Department Examination committee would undertake preparation of the result-sheets for the students.

c) Field Work: Fieldwork/visits is compulsory (amounting to 4 credits). At least 1 major interdisciplinary fieldwork (2 credits) and two visits (1 credit each) is envisaged separately or combined together and there will be a continuous evaluation of the same. The overall scheme for each credit evaluation is as follows:

Component	**Marks**	**Evaluating Authority**
Performance of the student in the field (Punctuality, enthusiasm, and aptitude)	05	Faculty accompanying the students
Field Diary	05	Faculty accompanying the student
Viva-voce	05	Faculty accompanying the student
Comprehensive Tour Report	10	By Departmental Committee

GPA Rules:

1. The formula for GPA will be based on Weighted Average. The final GPA will not be printed unless a student passes courses equivalent to minimum 80 credit hours (Science). Total credits hours mean the sum of credit hours of the courses which a student has passed.

2. A seven-point grade system [guided by the Government of Maharashtra Resolution No. NGO – 1298 / [4619] / UNI 4 dt. December 11, 1999 and University regulations] will be followed. The corresponding grade table is attached herewith.
3. If the GPA is higher than the indicated upper limit in the third decimal digit then the student be awarded higher final grade (e.g. a student getting GPA of 4.492 may be awarded 'A')

   For Semester I, II, III examinations, only the grade points will be awarded for each subjects. Final GPA along with final grade will be awarded only at the end of IVth semester. There is also a provision for verification and revaluation. In case of verification, the existing rules will be applicable. The revaluation result will be adopted if there is a change of at least 10% marks and in the grade of the course.
4. After the declaration of result, for the improvement of Grade, the student can reappear for the examination of 30 credit worth theory courses.

Explanation of Grade & Grade Point Average:

Marks Obtained	Grade	Grade Points
100 – 80	**'O'** Outstanding	10
79 - 70	**'A+'** Excellent	9
69 - 60	**'A'** Very Good	8

59 - 55	**‘B+’** Good	7
54 - 50	**‘B’** Above average	6
49 - 45	**‘C’** Average	5
44 - 40	**‘P’** Pass	4
39 -0	**‘F’** Fail	0
0	**Ab**	Absent

Final Grade Points:

Grade Points	Final Grade
10.0 - 9.0	**O**
8.99 - 8.5	**A+**
8.49 - 7.5	**A**
7.49- 6.5	**B+**
6.49 - 5.5	**B**
5.49- 4.25	**C**
4.24 - 4.0	**P**
>3.99	**F**

Common Formula for GPA:

Grade Point Average (GPA) = $\dfrac{\text{Total of (Grade Points earned x Credit hours for each course)}}{\text{(Total Credit hours)}}$

Note: The Departmental Examination Committee in consultation with Head of Departmental will have the full rights to make changes in the evaluation system but within the norms of the SPPU Board of Examination and Evaluation.

CHE/GEO/EVS/PHY 406 RM: Theory of research, research tools and methods (4 Credits, 60 L)

Fundamentals of Research Methodology (10 L)

Meaning, objectives, and significance of research, Types of research: basic, applied, experimental, analytical, and computational, Identification and formulation of research problems, Hypothesis formulation and testing, Research planning and research design, Interdisciplinary and multidisciplinary research approaches.

Literature Survey and Scientific Documentation (10 L)

Literature survey techniques, Use of scientific databases: Scopus, Web of Science, Google Scholar, arXiv, INSPIRE, Reference management software (Zotero, Mendeley, EndNote), presentation softwares (MS Powerpoint, MS eord, LaTex)

Scientific Communication and Research Practices (10 L)

Scientific communication and technical writing of evaluation report and thesis writing. Intellectual Property Rights (IPR), patents, copyrights, and trademarks Introduction to innovation and entrepreneurship in scientific research

Research Tools and Data Analysis (10 L)

Experimental and computational tools for research, Data acquisition and data processing techniques, Error analysis and uncertainty estimation, Graph plotting and curve fitting Statistical analysis and interpretation of data, Use of software tools (Origin, MATLAB/Python basics, Excel, gnuplot).

References

1. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International, 1990
2. B. L. Garg, R. Karadia, F. Agarwal and U. K. Agarwal, An introduction to Research Methodology, RBSA Publishers, 2002
3. S. M. Coley and C. A. Scheinberg, Proposal Writing, Sage Publications, 1990.
4. Research Methodology by Best and Kahn, PHI Limited.
5. Research Methodology by R. Kumar, A Step-By-Step Guide for Beginners, Pearson Education, Delhi (2006).
6. Fundamentals of modern statistical methods by Rand R.wilcox.
7. Power Analysis for Experimental Research A Practical Guide for the Biological, Medical and social Sciences by R. Barker Bausell, Yi-Fang Li Cambridge University Press.
8. Design of Experience: Statistical Principles of Research Design and Analysis, by Robert O. Kuehl Brooks/cole.
9. Panneerselvam R., Research Methodology, Prentice Hall Of India, New Delhi,2004
10. Design & Analysis of Experiments by D. C. Montgomery, 5th Ed., Wiley India (2007).

Course outcomes:

CO1: Develop a comprehensive understanding of different research methodologies and their applications in mathematics.
CO2: Cultivate critical thinking and analytical skills necessary for identifying research problems and formulating research questions.
CO3: Provide practical experience in designing experiments, collecting and analyzing data, and interpreting research results.
CO4: Foster effective communication skills for presenting research findings orally and in written form.
CO5: Promote ethical research practices and awareness of responsible conduct in mathematical research
CO5; Develop problem solving ability.

CHE/GEO/EVS/PHY 407 MJ (P): Fieldwork/Industrial training (2 Credits)

Students in this course will be required to do Fieldtrip/Internship in relevant industries/government sectors/institutes, likes university, IIT's, IISER's, CSIR-NCL etc to gain practical training. As a prerequisite for industrial training, the department may conduct necessary lectures/workshops/seminars. The course will be run as per the guidelines of the Institute /the University and Government of Maharashtra. Most of our graduates are expected to seek employment in industries, pursue teaching careers, or establish small enterprises after obtaining their B.Sc Blended honors degree. Therefore, the following options would be provided to the students to develop skilled and competent students.

a) Hands on Training on various analytical instruments- UV-Visible Spectrometer, Fourier Transform Infrared Spectrometer, Nuclear Magnetic Resonance Spectrometer, Mass Spectrometry, Gas Chromatography, HPLC, X-Ray Diffractometer, Powder X-ray Diffractometer, Thermal Analyzer (TGA-DSC), Scanning electron microscope, Transmission electron microscope, BET Surface Analyzer, Raman Spectrometer, CHN Analyzer
Note: Analytical instruments (from above list) should be selected for Traning that should complete 120 hours training**.**

OR

b) Teacher Training Course:

1) Development of MOOCS 2) Development of Learning Management System (LMS)

OR

c) Internship in Industry or National research laboratory.

OR

d) To develop Entrepreneurship, production of the following items, including packaging

1) Dye

2) Acids, caustic soda

3) Fire Extinguisher

4) Fertilizers

5) Any other industry material

OR

e) Field trip projects that are aligned with the Subject.

A detailed report should be submitted for the evaluation of field trip work /Internship.

CHE/GEO/EVS/PHY 432 RP: Dissertation (04 Credits)

Following guidelines should be followed for the conduction and evaluation of research project.

• Each student will perform project separately. • Project working hours should be 30 hours for each credit.

• Choose a topic that aligns with your interests and career goals, but also consider its feasibility within the available resources and time frame.

• Consult with faculty members, advisors, or mentors to identify a research area that has potential for contribution to the field of chemistry.

• Adhere to ethical principles and standards in all aspects of your research.

• Project report must be written systematically and presented in bound form: The project will consist of name page, certificate, content, summary of project followed by introduction, literature survey (recently published research papers must be included), experimental techniques, results and discussion, conclusions, Appendix consisting of i) references, ii) standard spectra / data if any and iii) safety precautions.

• If student is performing project in another institute, for such a student, internal mentor must be allotted and he will be responsible for internal assessment of a student. In this case student has to obtain certificate from both external and internal mentor. Systematic record of attendance of project students must be maintained by a mentor.

• Project will be evaluated jointly by three examiners and there will not be any practical performance during the examination. Typically, student has to present his practical work and discuss results and conclusions in details (20-30 min.) which will be followed by question-answer session (10 min). It is open type of examination.

• Students are encouraged to participate in national and international conferences and other project competitions.

Course Outcome:

CO-1. understand key concepts and principles relevant to the research topic.

CO-2. learn diverse research methodologies proficiently.

CO-3. write and communicate research findings persuasively through various mediums in the form of project report CO-4. analyze and synthesize scholarly literature effectively.

CO-5. evaluate research findings and methodologies critically. 6. design and execute original research projects independently.

Savitribai Phule Pune University

Pune, India

Faculty of Science and Technology

<u>Fourth year B.Sc. Blended Honors Program</u>

Subject: **CHEMISTRY**

Structure and Syllabus of Fourth Year

B.Sc. Blended Honors Program in Chemistry

(B.Sc. Blended Honors) Degree Program

Effective from Academic year 2026 – 2027

The syllabus has been developed through a participatory and consultative process involving extensive discussions with faculty members from the discipline of Physics, along with a careful review of existing curricula and contemporary academic requirements. In accordance with the directives of the University Grants Commission (UGC) and the framework of the National Education Policy (NEP–2020), the curriculum for the undergraduate Physics program has been designed to align with the objectives of multidisciplinary, outcome-based, and skill-oriented education.

Under the autonomous framework and in accordance with the revised guidelines issued by Savitribai Phule Pune University, the Interdisciplinary School of Science has designed the B.Sc. (Honors) Physics syllabus from the academic year 2024-2025 onwards. The curriculum has been designed for review of the Board of Studies in chemistry, keeping in view the contemporary relevance, emerging trends, and applications of various branches of chemistry.

The process of curriculum design was initiated through a series of academic deliberations and orientation programs conducted to familiarize faculty members with the vision, principles, and implementation framework of NEP-2020. These discussions enabled effective incorporation of the key aspects of the policy, including flexibility, interdisciplinarity, experiential learning, research orientation, and outcome-based education into the revised curriculum structure.

The learning outcome-based curriculum for the B.Sc. (Chemistry) program is intended to provide students with a strong conceptual foundation in Physics while simultaneously developing analytical thinking, problem-solving abilities, experimental skills, and research aptitude. The curriculum is designed to prepare students for higher education, research, industry, and other professional opportunities in the field of science and technology.

While framing the syllabus, due consideration has been given to the UGC Learning Outcomes-based Curriculum Framework (LOCF), the recommendations of NEP–2020, and the model curriculum prescribed by Savitribai Phule Pune University to ensure academic quality, relevance, and alignment with national educational objectives.

Structure of the Syllabus with Credit Framework

Fourth Year

<table>
<tr><th>Sem</th><th>Course Type</th><th>Course Code: Course Name</th><th>Credit</th><th>Sub Total</th></tr>
<tr><td rowspan="6">VII</td><td>Major Core</td><td>CHE 401 MJ: Advanced concepts in physical chemistry
CHE 402 MJ: Modern spectroscopic methods in structure determination of compounds
CHE 403 MJ: Chemistry of Macromolecules
CHE 407 MJ (P): RP/ FP/ Practical</td><td>04
04
04
02</td><td>14</td></tr>
<tr><td rowspan="4">Minor elective</td><td>CHE 404 MN: Modern concepts in molecular symmetry
CHE 405 MN: Advanced industrial formulation chemistry</td><td>02
02</td><td>04</td></tr>
<tr><td>Select any Two course from the entire course basket</td><td></td><td></td></tr>
<tr><td>From Swayam / MOOC Resources:</td><td></td><td></td></tr>
<tr><td>With prior approval of the Departmental Committee / BoS</td><td></td><td></td></tr>
<tr><td>Research Method</td><td>CHE 406 RM: Theory of research, research tools and methods</td><td>04</td><td>04</td></tr>
<tr><td></td><td></td><td>Total</td><td></td><td>22</td></tr>
<tr><td rowspan="6">VIII</td><td>Major Core</td><td>CHE 451 MJ: Coordination and Bioinorganic chemistry
CHE 452 MJ: Advanced synthetic organic Chemistry
CHE 453 MJ: Green Chemistry & its application
CHE 457 MJ (P): RP/ FP/ Practical</td><td>04
04
04
02</td><td>14</td></tr>
<tr><td rowspan="4">Minor elective</td><td>CHE 454 MN: Analytical methods for material characterization.
CHE 455 MN: Polymer Chemistry</td><td>02
02</td><td>04</td></tr>
<tr><td>Select any ONE course from the entire course basket</td><td></td><td></td></tr>
<tr><td>From Swayam / MOOC Resources:</td><td></td><td></td></tr>
<tr><td>With prior approval of the Departmental Committee / BoS</td><td></td><td></td></tr>
<tr><td>Res. Project/ Fieldwork</td><td>CHE 432 RP: Dissertation</td><td>04</td><td>04</td></tr>
<tr><td></td><td></td><td>Total</td><td></td><td>22</td></tr>
</table>

Semester VII

CHE 401 MJ: Advanced concepts in physical chemistry (4 Credits, 60 L)

Thermodynamics (15 L)

State function, path function, exact and inexact differential, Maxwell's relationship, temperature and pressure dependence of thermodynamic quantities, Clausius inequality, chemical potential, variation of chemical potential with temperature and pressure, chemical potential in a system of ideal gases, Determination of partial molar quantities, Methods for the determination of molar quantities, Thermodynamics of mixing, Entropy of mixing, Numerical problems.

Quantum chemistry (15 L)

Recapitulation, Postulates of quantum chemistry, operators- Algebra of operators, commutator operator, linear operators, observables in classical mechanics and corresponding operators in quantum mechanics, simple derivation of Schrodinger wave equation using momentum/energy operator, particle in one dimensional box, particle in three dimensional box, Degeneracy, Normalization and orthogonality of wave functions, rigid rotor, and one dimensional simple hydrogen like atom (no deviation), Numerical problems.

Chemical kinetics (20 L)

a) Rate law: Recapitulation, the temp dependent reaction rate, reaction moving towards equilibrium, pre equilibria, The steady state approximation (SSA), consecutive reactions (analysis with and without SSA), application of SSA to reaction between H2 and Br2, parallel reactions, Lindemann theory of unimolecular reactions. Numerical problems.

b) Kinetics of complex reactions: chain reactions, free radical polymerization, explosive reactions, Numerical problems. Molecular reaction dynamics: Collision theory of bimolecular, diffusion controlled and activation-controlled reaction in solution, activated complex theory of reaction rate, Eyring equation. Potential energy surfaces, Numerical problems.

c) Enzyme catalysis: Introduction, Enzymes and effect of pH and temperature on enzyme catalysed reactions (qualitative), Michaelis Menten equation, limiting rate, Lineweaver -Burk, Eadie-Hofstee methods and plots, competitive, uncompetitive and non-competitive inhibition, Numerical problems.

Molecular Thermodynamics (10 L)

Molecular energy levels, Boltzmann distribution law, partition functions and ensembles, translational, rotational and vibrational partition function of diatomic molecules, Thermodynamic properties in terms of partition functions (internal energy, heat capacity, entropy and equilibrium constant), Maxwell-Boltzmann, Fermi- Dirac and Bose -Einstein statistics.

References:

1. Physical chemistry by Peter Atkins, Julio De Paula, 11th Edition , 2018, Oxford University Press

2. Principals of Physical chemistry by Puri Sharma Pathania, 48th edition, Vishal Publishing Co.

3. Physical chemistry by GM borrow, 5th edition , 2006, Mc Graw Hill Education

4. Quantum chemistry by Ira Levine, 6th Edition

5. Quantum chemistry by R.K. Prasad, 4th Edition

6. Physical chemistry by biological sciences by Raymond Chang (Page Number 113, 135, 141)

7. Principles of Physical Chemistry by Marron and Prouton, 4th edition

8. Physical Chemistry: A Molecular Approach by by Donald A. McQuarrie, John D. Simon (20 August 1997)

Course Outcomes

CO1: Students should be able to remember the concepts of thermodynamic parameters, quantum mechanical postulates, rate laws of chemical reactions and computation of macroscopic properties of matter.

CO2: Students should understand the basics like state function and path function, Schrodinger wave equation, kinetics of fast reactions, partition functions and ensembles.

CO3: Students should be able to apply the knowledge of various quantum mechanical methods to determine the different molecular properties and built the concept of the relation between thermodynamics and quantum mechanics.

CO4: Students should be able to analyze the rates of various chemical reactions both theoretically and experimentally and also observe the effect of catalyst and determine energies of activation of such reactions.

CO5: Students should be able to evaluate variation of thermodynamic parameters for multi component systems and their variation with other extensive properties, Schrodinger wave equation and its application to hydrogen and hydrogen like atoms.

CO6: Students should be able to create the solutions to avoid excess use of energy in chemical reactions by applying their knowledge of thermodynamics and chemical kinetics.

CHE 402 MJ: Modern spectroscopic methods in structure determination of organic compounds (4 Credits, 60 L)

^{1}H NMR Spectroscopy (20 L)

Recapitulation of basic principle, Fourier Transform technique, Pulse sequence, relaxation processes. different types of spin coupling, first order analysis of spectra, different spin systems (AB, AM, AX, ABX/AMX spin systems with examples), factors affecting coupling constants, non-equivalence due to restricted rotations, rate processes. Simplification of complex spectra (High field NMR, Spin Decoupling, Shift reagent, NOE, Chiral Solvents, D_2O exchange, etc.), ^{31}P, ^{s}F NMR (Problems based on number of signals and splitting pattern).

^{13}C NMR Spectroscopy (15 L)

Principle, Types of ^{13}C NMR Spectra: un-decoupled, Proton decoupled, off resonance, APT, INEPT, DEPT, chemical shift, factors affecting chemical shifts, Homo nuclear (^{13}C-^{13}C) and Hetero nuclear (13C-1H) coupling constants.

2D NMR Spectroscopy in structure elucidation (05 L)

(a) Homonuclear: COSY, TOCSY, 2D INADEQUATE, 2DADEQUATE, NOESY, ROESY (b) Heteronuclear: HETCOR, HSQC, HMQC, HMBC.

Mass Spectrometry (10 L)

Principle, ionization methods like EI, CI, ESI, MALDI and FAB, Fragmentation of typical organic compounds, stability of fragments, Rearrangements, factors affecting fragmentation, ion analysis, ion abundance, High-Resolution mass spectrometry in determination of molecular formula.

Problems solving (15 L)

Structure elucidation using UV, IR, 1D (1H and13C) NMR and 2D NMR (1H1H, COSY / ^{13}C, ^{1}H HETCOR only), APT, DEPT and MS data as well as spectra. Use of NMR fid processing software's for Visualization, processing, analysing and making reports of ^{1}H-NMR, ^{13}C NMR and 2D NMR.

References:

1. Spectrometric Identification of Organic Compounds by R. M. Silverstein, F. X.Webster, D. Kiemle, 6th Ed. John Wiley and Sons..
2. One and Two dimensional NMR Spectroscopy by Atta-Ur-Rehman, Elsevier (1989).
3. Structure determination of Organic compounds by E. Pretsch, P. Buhlman, and C. Affolter, Springer (2005).
4. Spectroscopy of organic molecule-P S Kalsi,Wiley, Esterna, New Delhi.
5. Introduction to Spectroscopy – D. L. Pavia, G.M. Lampman, G. S. Kriz, 5thEd. (Harcourt college publishers).
6. Organic Structures from Spectra by Field L.D. Kalman J.R. and Sternhell S. 4th Ed. John Wiley and Sons Ltd.
7. Organic Structural Spectroscopy by Joseph B. Lambert, Shurvell, Lightner, Cooks, Prentice-Hall (1998).
8. Organic Structure Analysis-Phillip Crews, Rodriguez, Jaspars by Oxford University Press (1998).

Course outcome:

After completion of this course, the student will student will be able to

CO1: Learn the fundamental knowledge of 1H NMR, 13C NMR, 19F NMR and Mass Spectral techniques.

CO2: Acquire advanced knowledge of 1H NMR, 13C NMR, 19F NMR and Mass Spectral techniques.

CO3: Apply the knowledge of 1H NMR, 13C NMR, 19F NMR and Mass Spectral techniques for structure determination.

CO4: Discuss probable spectral signals.

CO:5: Interpret different types of spectra. CO6: Deduce the structure of the unknown compound using 1H NMR, 13C NMR and Mass Spectra.

CHE 403 MJ: Chemistry of Macromolecules (4 Credits, 60 L)

Basic concepts - classification, nomenclature, molecular weights, molecular weight distribution, glass transition, degree of crystallinity, morphology, and viscosity molecular weight, mechanical property - molecular weight relationships.

Molecular weights and Methods of determination, molecular weight distribution, size and shape of macromolecules. Intrinsic viscosity, Mark-Houwink relationship.

Chain structure and configuration, conformation, size of an ideal chain (freely jointed chain and other models), Real chains, Flory theory.

Thermodynamics of polymer solutions.

Molecular motion (self-diffusion, hydrodynamic radius, Rouse Model, Zimm Model, entangled polymer dynamics and de Gennes reptation model).

Glass transition temperature – elementary theories and methods of determination. Variation of glass transition with structure.

Rubber elasticity - concepts, thermodynamic equation of state. Elementary theories of viscoelasticity (Maxwell, Voight).

Mechanisms and Methods of Polymerization - Step (condensation) polymerization - Description -

Reactivity Functional Groups - Kinetic and thermodynamic considerations - Molecular weight distribution. Chain polymerization, controlled radical polymerizations (INIFERTER, ATRP, RAFT, SET). Living Polymerizations. Ziegler-Natta and metathesis polymerizations.

Course Learning Outcomes:

After successful completion of the course, students will be able to:

1. Understand the classification, nomenclature, and molecular characteristics of polymers.
2. Explain molecular weight concepts and characterization techniques.
3. Describe polymer chain structure, conformation, and polymer solution thermodynamics.
4. Analyze molecular motion, glass transition, and viscoelastic behavior of polymers.
5. Understand the principles of rubber elasticity.
6. Explain various mechanisms and advanced methods of polymerization, including controlled radical, living, coordination, and metathesis polymerizations.

Reference:

1. R. J. Young and P. A. Lovell, Introduction to Polymers, 2nd Edition, Chapman and Hall, 2002.
2. F. W. Billmeyer, Textbook of Polymer Science, 3rd Edition, John Wiley, 1994.
3. V. R. Gowariker, N. V. Viswanathan, Jayadev Sreedhar, New Age International (P) Ltd, 2005.
4. G. Odian, Principles of Polymerization, Fourth edition, Wiley-Interscience, 2004.
5. L. H. Sperling, Introduction to Physical Polymer Science, Wiley- Interscience, 1986.
6. M. Rubinstein and R. A. Colby, Polymer Physics, Oxford University Press, 2003.

CHE 404 MN: Modern concepts in molecular symmetry (2 Credits, 30 L)

Molecular Symmetry and Symmetry Groups (15 L)

Symmetry elements and operations, Symmetry planes and reflections, the inversion centre, proper axes and proper rotations, improper axes and improper rotation, products of symmetry operations, equivalent symmetry elements and equivalent atoms, general relations among symmetry elements and symmetry operations, classes of symmetry operations, symmetry elements and optical isomerism, symmetry point groups, classification of molecular point groups, defining properties of a group, group multiplication table, some examples of group, subgroups and classes

Representations of Groups (10 L)

Matrix representation and matrix notation for geometric transformation, The Great Orthogonality Theorem and its consequence, character tables (No mathematical part), wave function as basis for irreducible representations

Symmetry Adapted Linear Combinations (05L)

Projection operators and their use of construct SALC (Construction of SALC for sigma bonding for molecules belonging point groups D2h, D3h, D4h, C4v, Td, Oh normalization of SALC, transformation properties of atomic orbital, MO's for sigma bonding, ABn molecules, tetrahedral AB4 and Oh AB6 cases.

References:

1. Chemical Applications of Group Theory by F. A. Cotton Third Edition, (Wiley, New York)
2. Symmetry and Spectroscopy of Molecules by K. Veera Reddy Second Edition 2009: (New Age International Publication)
3. Group Theory and its Chemical Application, P.K. Bhattacharya
4. Symmetry in Chemistry by H. Jaffe and M. Orchin, Himalaya Pub.House-New Delhi,

Course Outcomes: At the end of course student should able to

CO-1: Define symmetry elements and symmetry operations, classes, properties of a group, group multiplication table, etc.

CO-2: Classify symmetry elements, point group, Group, sub-group and classes.

CO-3: Use wave function as basis for determination of irreducible representations and the Great Orthogonality theorem and its consequence.

CO-4: Solve problem based on point group, matrix representation and character table

CO-5: Construct character table of various point group

CO-6: Justify which can take part in bonding on the basis of SALCs and point group of molecules.

CHE 405 MN: Advanced industrial formulation chemistry **(2 Credits, 30 L)**

Dyes (5 L)

Introduction: Classification of dyes based on chemical constitution (azo, anthraquinone, nitro, triphenylmethane) and application methods (acid, basic, direct, reactive, vat, disperse).

Color and Constitution: Chromophore-auxochrome theory, resonance, and molecular orbital theory.

Synthesis & Application: Industrial manufacturing process for major dyes (e.g., Methyl Orange, Malachite Green, Congo Red).

Pigments (5 L)

General characteristics, types (inorganic and organic pigments), blue pigments, red pigments, black pigments, and their industrial applications.

Application Technology: Dyeing of cotton, wool, and silk; color fastness testing (washing, rubbing)

Paint and Coating Technology (10 L)

Constituents of Paints: Binders/Resins (alkyd, epoxy), Pigments (prime and extenders), Solvents, and Additives. Paint Manufacturing: Processes including grinding, dispersing, and mixing; ball mill, triple roll mill, high-speed dispersers. Types of Paints: Emulsion paint, latex paint, distemper, luminescent paints, and varnishes. Formulation & Evaluation: Important aspects of PVC (Pigment Volume Concentration), paint failure, and methods of application

Polymer Chemistry and Technology (10 L)

Fundamentals: Classification of polymers (natural, synthetic, thermoplastic, thermosetting).

Polymerization Mechanisms: Bulk, solution, emulsion, and suspension polymerization.

Industrial Polymers: Production of Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyvinyl Chloride (PVC), Polyamides (Nylon), and Polyesters.

Resin Technology: Phenolic resins (novolac, resol), urea-melamine resins, epoxy resins, and alkyd resins. Characterization: Techniques for determining molecular weight and mechanical properties

Reference:

1. Shore, J. (1995). Colorants and Auxiliaries: Volume 2: Auxiliaries. Society of Dyers and Colourists.

2. Trotman, E. R. (1984). Dyeing and Chemical Technology of Textile Fibres. Charles Griffin & Company.

3. Flick, E. W. (2017). Water-Based Trade Paint Formulations. Elsevier.

4. Herbst, W., & Hunger, K. (2004). Industrial Organic Pigments: Production, Crystal Structures, Properties, Applications (4th ed.). Wiley-VCH.

5. Vogel, A. I. Vogel's Textbook of Organic Chemistry.

6. Gowariker, V. R. Polymer Science.

7. NPCS Board. The Complete Technology Book on Industrial Polymers, Additives, Colourants and Fillers.

Course Outcome:

CO-1: Understand Dye Chemistry: Classify dyes, explain their structure-color relationship, and outline the industrial synthesis of key colorants.

CO-2: Evaluate Pigments: Describe the production and properties of inorganic/organic pigments and their role in surface coatings.

CO-3: Formulate Paints: Identify the components and manufacturing processes of paints, including the role of binders and solvents.

CO-4: Analyze Polymers: Differentiate between polymerization mechanisms and identify commercial applications of major plastics.

CO-5: Develop Technical Skills: Conduct synthesis of dyes and testing of industrial products (fastness, viscosity) in a laboratory setting.

CHE 406 MJ: Theory of research, research tools and methods (4 Credits, 60 L)

Fundamentals of Research Methodology (10 L)

Meaning, objectives, and significance of research, Types of research: basic, applied, experimental, analytical, and computational, Identification and formulation of research problems, Hypothesis formulation and testing, Research planning and research design, Interdisciplinary and multidisciplinary research approaches.

Literature Survey and Scientific Documentation (10 L)

Literature survey techniques, Use of scientific databases: Scopus, Web of Science, Google Scholar, arXiv, INSPIRE, Reference management software (Zotero, Mendeley, EndNote), presentation software (MS Powerpoint, MS eord, LaTex)

Scientific Communication and Research Practices (10 L)

Scientific communication and technical writing of evaluation report and thesis writing. Intellectual Property Rights (IPR), patents, copyrights, and trademarks Introduction to innovation and entrepreneurship in scientific research

Research Tools and Data Analysis (10 L)

Experimental and computational tools for research, Data acquisition and data processing techniques, Error analysis and uncertainty estimation, Graph plotting and curve fitting Statistical analysis and interpretation of data, Use of software tools (Origin, MATLAB/Python basics, Excel, gnuplot).

References

1. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International, 1990

2. B. L. Garg, R. Karadia, F. Agarwal and U. K. Agarwal, An introduction to Research Methodology, RBSA Publishers, 2002

3. S. M. Coley and C. A. Scheinberg, Proposal Writing, Sage Publications, 1990.

4. Research Methodology by Best and Kahn, PHI Limited.

5. Research Methodology by R. Kumar, A Step-By-Step Guide for Beginners, Pearson Education, Delhi (2006).

6. Fundamentals of modern statistical methods by Rand R.wilcox.

7. Power Analysis for Experimental Research A Practical Guide for the Biological, Medical and social Sciences by R. Barker Bausell, Yi-Fang Li Cambridge University Press.

8. Design of Experience: Statistical Principles of Research Design and Analysis, by Robert O. Kuehl Brooks/cole.

9. Panneerselvam R., Research Methodology, Prentice Hall Of India, New Delhi,2004

10. Design & Analysis of Experiments by D. C. Montgomery, 5th Ed., Wiley India (2007).

Course outcomes:

CO1: Develop a comprehensive understanding of different research methodologies and their applications in mathematics.
CO2: Cultivate critical thinking and analytical skills necessary for identifying research problems and formulating research questions.
CO3: Provide practical experience in designing experiments, collecting and analyzing data, and interpreting research results.
CO4: Foster effective communication skills for presenting research findings orally and in written form.
CO5: Promote ethical research practices and awareness of responsible conduct in mathematical research
CO5; Develop problem solving ability.

CHE 407 MJ (P): FP/ RP/ Practical (2 Credits)

Students in this course will be required to do Fieldtrip work / Internship in relevant industries/government sectors/institutes, likes university, IIT's, IISER's, CSIR-NCL etc to gain practical training. As a prerequisite for industrial training, the department may conduct necessary lectures/workshops/seminars. The course will be run as per the guidelines of the Institute /the University and Government of Maharashtra. Most of our graduates are expected to seek employment in industries, pursue teaching careers, or establish small enterprises after obtaining their B.Sc Blended honors degree. Therefore, the following options would be provided to the students to develop skilled and competent students.

a) Hands on Training on various analytical instruments- UV-Visible Spectrometer, Fourier Transform Infrared Spectrometer, Nuclear Magnetic Resonance Spectrometer, Mass Spectrometry, Gas Chromatography, HPLC, X-Ray Diffractometer, Powder X-ray Diffractometer, Thermal Analyzer (TGA-DSC), Scanning electron microscope, Transmission electron microscope, BET Surface Analyzer, Raman Spectrometer, CHN Analyzer

Note: Analytical instruments (from above list) should be selected for Traning that should complete 120 hours training**.**

OR

b) Teacher Training Course:

1) Development of MOOCS   2) Development of Learning Management System (LMS)

OR

c) Internship in Industry or National research laboratory.

OR

e) Field trip projects that are aligned with the Subject.

A detailed report should be submitted for the evaluation of field trip work /Internship.

Learning Outcomes

Upon successful completion of the Fieldwork / Industrial Training / Internship course, students will be able to:

1. Gain practical exposure to industrial, research laboratory, academic, and field-based working environments relevant to Physics and interdisciplinary sciences.
2. Develop hands-on skills in the operation, handling, and analysis of advanced scientific and analytical instruments.
3. Understand laboratory safety procedures, experimental protocols, data acquisition, and interpretation techniques used in research and industry.
4. Apply theoretical concepts learned in coursework to real-world scientific, industrial, and technological problems.
5. Enhance problem-solving, technical communication, teamwork, and professional ethics essential for research and industry careers.

Evaluation Strategies

Component	Marks	Evaluation Authority
Attendance and Participation during Training	10	Industry/Institute Mentor
Practical Skills and Technical Performance	20	Industry/Institute Mentor
Training Logbook / Laboratory Record	10	Departmental Committee
Internship / Fieldwork Report	25	Departmental Committee
Seminar Presentation	15	Departmental Committee
Viva-Voce Examination	20	Joint Evaluation Committee

Total Marks: 50

Guidelines for Evaluation

1. Students must complete the prescribed duration of training/internship/fieldwork (minimum 120 hours wherever applicable).
2. A detailed technical report documenting objectives, methodology, observations, analysis, and outcomes must be submitted.
3. Students are required to present their work through a seminar or presentation before the departmental committee.
4. Evaluation shall be based on technical understanding, practical skills acquired, quality of report, presentation, and viva-voce performance.

Semester VIII

CHE 451 MJ: Coordination and Bioinorganic chemistry (4 Credits, 60 L)

Coordination Chemistry: Concept and Scope of Ligand Fields (06 L)

Quantum numbers, Free ion Configuration, Terms and States, Energy levels of transition metal ions, free ion terms, microstates, term wave functions, spin-orbits coupling.

Ligand Field Theory of Coordination Complexes (08 L)

Effect of ligand field on energy levels of transition metal ions, weak cubic ligand field effect on Russell- Saunders terms, Orgel diagrams, strong field effect, correlation diagrams, Tanabe- Sugano Diagrams, Spin-Pairing energies.

Electronic spectra of Transition Metal Complexes (08 L)

Introduction, band intensities, band energies, band width and shapes, transition metal spectra of 1st, 2ndand 3rd row ions and complexes, electronic spectra of Lanthanide and Actinide, spectrochemical and nephelauxetic series, charge transfer and luminescence spectra, calculations of Dq, B, β parameters, percentage of covalent character for metal complexes.

Magnetic Properties of Coordination Complexes (08 L)

Origin magnetism, types of magnetism, Curie law, Curie-Weiss Law, Magnetic properties of Complexes-Para magnetism, 1stand 2nd Ordered Zeeman effect, quenching of orbital angular momentum by Ligand fields, Magnetic properties of A, E and T ground terms in complexes, spin free and spin paired equilibria, temperature dependence of magnetism.

Reference

1. Ligand Field Theory and Its Applications by B.N. Figgis and M.A. Hitachman (Wiley India Pvt Ltd, 12 October 2010)

2. Symmetry and Spectroscopy of Molecules by K. Veera Reddy, Second Edition 2009: (New Age International Publication)

3. Elements of Magnetochemistry by R. L. Datta and A. Syamal, Second Edition

Course Outcomes: At the end of course student should able to –

CO-1: Define R. S. term, configuration, microstate, paramagnetic, diamagnetic ferromagnetic, antiferromagnetic, Curie and Neel temperature.

CO-2: Identify complex ions showing same R.S. terms, degeneracy of ground state terms of metal ions, and spin multiplicities of different configurations.

CO-3: Interpret electronic spectra for spin allowed Oh and Td complexes using Orgel diagram, Magnetic properties of A, E and T ground terms in complexes and selection rules.

CO-4: Calculate frequencies of absorption spectrum, 10Dq, Racah and nepholauxetic parameter for a complex, and magnetic moments of complexes

CO-5: Construct microstate table for various configuration and prepare correlations diagram and Tanabe-Sugano diagram for various configurations in Td an Oh ligand field.

CO-6: Assess appropriate full spectroscopic terms for various configuration/ion/term.

Bioinorganic Chemistry: Introduction of Bioinorganic Chemistry (04 L)

Historical Background and current relevance, role of Cu, Fe, Mn and Mo in metalloprotein, and metalloenzymes, Metals in medicine.

Role of Inorganic Chemistry in Bioinorganic Research Thermodynamic Aspect (09 L)

HSAB concept, chelate effect and Irving-William series, pKa values of coordinated ligands, Tuning of redox potential, Biopolymer effects. Kinetic aspects- Electron transfer reaction, Electronic substitution reaction. Reactions of coordinated ligands and Template effect, concept of spontaneous self-assembly model compounds.

Functions and Transport of Alkali and Alkaline Earth Metal Ions (07 L)

Importance of alkali and alkaline earth metals, Distribution of cationic and anionic electrolytes in blood plasma and intracellular fluid, Ionophores: Natural and Synthetic, Application of ionophores, Different mechanism involved in exchange of ions across cell-wall,Na+/K+- ATPase ion pump for active transport of Na+ and K+;.

Choice, Uptake and Assembly of Metal-Containing Units in Biology (05 L)

Bioavailability of metal ions, Enrichment strategies and intracellular chemistry of low abundance metal, Spontaneous self-assembly of metal cluster (FeS cluster)

Miscellaneous Topics of Bio-Inorganic Chemistry (05 L)

(a) Ca in Blood coagulation. (b) Magnesium in Photosystem I (c) Manganese in Photosystem II Ref- (d) Iron in Ferritin, Transferrin, Porphyrin based system. (e) Zinc Finger protein, Calmodulin, Mercury detoxification;

References:

1. Principles of Bioinorganic Chemistry by S.J. Lippard and J. M. Berg

2. Bioinorganic Chemistry: Inorganic Elements in Chemistry of Life by W.Kaim and B. Schwederski. 2nd Edition

3. Biological Inorganic Chemistry by Robert R. Crichton, 2nd Edition

4. Mikaelsson, M. E. (1991). The Role of Calcium in Coagulation and Anticoagulation. Coagulation and Blood Transfusion, 29– 37. doi:10.1007/978- 1-4615-3900-1_3

Course Outcomes:

CO-1: Define metalloproteins, metallo-eznymes, photosynthesis, HSAB concept, nucleic acids, metalloregulation, Biopolymer effects and acetylcholine receptor.

CO-2 : Explain chelate effect and Irving-William series, pKa values of coordinated ligands, Tuning of redox potential, and Reactions of coordinated ligands.

CO-3: Describe Fe-S clusters, model compounds and spontaneous self-assembly, metals in medicine, blue copper proteins, and cytochromes, and Na/K pumps.

CO-4: Express nitrogen fixation, detoxification of mercury, structure of RNA, cis-platin, amino acids, siderophore,and calmoduline zinc finger proteins.

CO-5: Distinguish between hemoglobin and myoglobin, transferrin and ferritin, photosystem-I and photosystem-II.

CO-6: Decide role of metals in biological system, medicine, blood coagulation, oxygen storage and transport, photosynthesis and uptake and transport of iron

CHE 452 MJ: Advanced synthetic organic chemistry (4 Credits, 60 L)

Synthetic applications of Transition metal complexes in organic synthesis (06 L)

Pd, Ni, Co, Ru, Fe, and Cu (only C-C, C-N, C-O bond formation reactions with catalytic cycle, terminology in Catalysis, Turnover number (TON), Turnover Frequency (TOF), oxidation states of transition metals, 16-18 rule, dissociation, association, insertion, oxidative addition, reductive elimination of transition metal ligand, and % mole concepts)

Synthetic applications of Organo-Palladium reagents (12 L)

Heck arylation, allylic activation, carbonylation, Wacker oxidation, Stille, Sonogashira, Fukuyama, Kumada, Hiyama, Negeshi, Tsuji-Trost, Buchwald-Hartwig and Suzuki coupling reactions.

Organo-Nickel reagents: Carbonylation, Oligomerisation and Reppe reaction. **(3 L)**

Organo-Iron reagents: Noyori reaction, Collmann's reagent, and Eletrophilic reactions. **(3 L)**

Organo-Cobalt reagents (3 L)

Oxo Process, Nicholas reaction, Pausand Khand reaction, Volhardt's cotrimerisation reaction.

Organo-Ruthenium and Organo-Rhodium reagents (3 L)

Reduction reactions using Wilkinson's Catalyst, Noyori reduction, Knowles asymmetric hydrogenation.

Metathesis Reactions (12 L)

Olefin metathesis, Schrock and Grubbs catalyst, Olefin cross coupling (OCM), ring closing (RCM) and ring opening (ROM) metathesis, application in polymerization and synthesis of small organic molecules, and application in the synthesis of homo and heterocyclic compounds. Enyne methathesis, Alkyne meththesis.

Click chemistry (3 L)

Criterion for click reaction, Sharpless azides cycloadditions, Sharpless asymetric epoxidation. Regioselectivity in click reactions, Click reactions in synthesis of bioconjugates (sugars and proteins)

Molecular Rearrangements (10 L)

Mechanism to nucleophilic, electrophilic, and free radical molecular rearrangements, migratory aptitude Carbon-carbon rearrangements: Pinacol-Pinacolone, Favorskii, Wolff and Benzil-Benzilic acid rearrangements Carbon-nitrogen rearrangements: Hoffmann, Curtius, Lossen, Schmidt and

Beckmann rearrangements. Carbon-oxygen rearrangements: Bayer-Villiger rearrangement, Dakin oxidation Oxygen-Carbon rearrangement: Fries rearrangement

Problem solving

Retrosynthetic Analysis (08 L)

Retrosynthetic analysis, disconnection approach, Synthons, multiple step synthesis, functional group interconversion, Illogical two group interconversion, C-C disconnection, Donor and acceptor Synthons, two group disconnection, 1,5 related functional group disconnection, Umpolung, convergent synthesis, special methods for small rings, Heteroatom and Heterocyclic compounds, problems,

References:

1. Organic synthesis – Michael B. Smith
2. Transition Metal Reagents and Catalysis Innovations in Organic Synthesis – Jiro Tsuji, JOHN WILEY & SONS, LTD
3. Some modern methods of organic synthesis – W. Carruthers(Cambridge)
4. Advanced organic chemistry, Part B – F. A Carey and R. J.Sundberg, 5th edition (2007).
5. Strategic Applications of named reactions in organicsynthesis-Laszlo Kurti and Barbara Czako
6. Modern Organic Synthesis: An Introduction George S Zweifel and Michael H Nantz
7. Name Reactions Jie Jack Li (Fourth Expanded Edition), PageNo: 1-582.
8. Organic Synthesis Using Transition Metals, by Roderick Bates, Second Edition, A John Wiley & Sons, Ltd., Publication.
9. Organic chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press),
10. Transition Metals for Organic Synthesis Volume 1 Edited by M. Beller and C. Bolm WILEY-VCH Verlag GmbH & Co. KGaAISBN: 3-527-30613-7
11. Multicomponent Reactions Edited by Jieping Zhu, HuguesBienayme WILEYVCH Verlag GmbH & Co. KGaA
12. C–N bond forming cross-coupling reactions: an overview: by Jitender Bariwalab and Erik Van der Eycken Chem. Soc. Rev., 2013, 42, 9283
13. Iron Catalysis in Organic Synthesis Chem. Rev. 2015, 115, 3170– 3387.
14. Recent advances in homogeneous nickel catalysis Nature 2014,Vol 509, Page 299- 309.
15. Ruthenium-Catalyzed Reactions for Organic Synthesis Chem. Rev. 1998, 98, 2599-2660.
16. Organic Synthesis Involving Iridium-Catalyzed Oxidation Chem. Rev. 2011, 111, 1825–1845.
17. Aerobic Copper-Catalyzed Organic Reactions Chem. Rev. 2013,113, 6234−6458.
18. Designing Organic Syntheses by Stuart Warren
19. Organic Chemistry from Retrosynthesis to Asymmetric Synthesis, by Vitomir Sunjic, Springer; 1st ed. 2016 edition
20. Classics in Total Synthesis by K.C. Nicolaou and E.J.Sorensen
21. Organic Synthesis Workbook II C. Bittner, A. S. Busemann, U. Griesbach, F. Haunert, W.-R.Krahnert, A. Modi, J.Olschimke, P.L. Stech

22 .Advanced Organic Chemistry by Dr. Jagdamba Singh & Dr. L.D.S. Yadav

Course Outcomes:

After the completion of this course, students will be able to

CO1: Learn the fundamental concepts of organometallic reactions and their bonding, reactivity, and mechanism.

CO2: Understand the significance of advanced organometallic reagents in organic chemistry.

CO3: Employ synthetic methodologies for cross-coupling reactions, enabling the formation of CC, C-N, and other bonds.

CO4: Analyze the products of synthetic organic reactions.

CO5: Relate the products of the retrosynthetic transformations with the Target Molecules.

CO6: Design the summary of advanced synthetic reagents, their reactions and the products.

CHE 453 MJ: Green Chemistry and Its applications. (4 Credits, 60 L)

UNIT-I: Basic Principles of Green Chemistry: Introduction- Need for Green Chemistry. Goals of Green Chemistry. Limitations of Green Chemistry. Chemical accidents, terminologies, International green chemistry organizations and Twelve principles of Green Chemistry with examples.

UNIT-II: Green Synthesis: Choice of starting materials, reagents, catalysts and solvents in detail, Green chemistry in day today life. Designing green synthesis-Green reagents: dimethyl carbonate. Green solvents: Water, Ionic liquids- criteria, general methods of preparation, effect on organic reaction. Supercritical carbon dioxide- properties, advantages, drawbacks and a few examples of organic reactions in scCO2. Green synthesis-adipic acid and catechol.

UNIT-III: Green Catalysis: Environmental pollution, Green Catalysis Acid catalysts, Oxidation catalysts, Basic catalysts, Polymer supported catalysts-Poly styrene aluminum chloride, polymeric super acid catalysts, Polymer supported photosensitizers.

UNIT-IV: Greener Reactions: Phase transfer catalysis in green synthesis-oxidation using hydrogen peroxide, crown ethers- esterification, saponification, anhydride formation, Elimination reaction, Displacement reaction. Applications in organic synthesis.

UNIT-V: Green Techniques: Micro wave induced green synthesis- Introduction, Instrumentation, Principle and applications. Sonochemistry– Instrumentation, Cavitation theory- Ultra sound assisted green synthesis and Applications

Course Outcomes (COs)

- Explain the fundamental concepts, principles, goals, and significance of Green Chemistry, and evaluate its role in sustainable chemical processes and environmental protection.
- Select appropriate green starting materials, reagents, catalysts, and solvents, and design environmentally benign synthetic routes using green chemistry principles.
- Analyze the role of green catalysts and catalytic systems in reducing pollution and improving the efficiency and sustainability of chemical transformations.
- Apply green reaction methodologies, including phase transfer catalysis and environmentally friendly oxidation, substitution, elimination, and esterification reactions, for sustainable organic synthesis.
- Demonstrate the principles and applications of modern green techniques such as microwave-assisted synthesis and sonochemistry, and assess their advantages over conventional synthetic methods.

Recommended Text Books:

1. Ahluwalia, V.K. and Kidwai, M.R. New Trends in Green Chemistry, Anamalaya Publishers, 2005.

2. W. L. McCabe, J.C. Smith and P. Harriott, Unit Operations of Chemical Engineering, 7th edition, McGraw-Hill, NewDelhi,2005.

3. J. M. Swan and D. St. C. Black, Organometallics in Organic Synthesis, Chapman Hall, 1974.

4. V. K. Ahluwalia and R. Aggarwal, Organic Synthesis: Special Techniques, Narosa Publishing House, New Delhi,2001.

5. A. K. De, Environmental Chemistry, New Age Publications, 2017.

Reference Books:

1. Anastas, P.T. and Warner, J.K. Oxford Green Chemistry-Theory and Practical, University Press, 1998
2. Matlack, A.S. Introduction to Green Chemistry, Marcel Dekker, 2001

3. Cann, M.C. and Connely, M.E. Real-World Cases in Green Chemistry, American Chemical Society, Washington, 2000

4. Ryan, M.A. and Tinnesand, M., Introduction to Green Chemistry, American Chemical Society Washington, 2002.

5. Chandrakanta Bandyopadhyay, An Insight into Green Chemistry, Books and Allied (P) Ltd, 2019.

CHE 454 MN: Analytical methods for material characterization. (2 Credits, 30 L)

X-Ray Diffraction Methods (08 L)

Miller and Weiss indices, X-Ray Radiation, Generation of X-Rays, X-Ray Absorption, Theoretical Background of Diffraction, Diffraction Geometry, Bragg's Law, Reciprocal Lattice, Diffraction Intensity, Structure Extinction, X-Ray Diffractometry, Instrumentation, System Aberrations, Samples and Data Acquisition, Sample Preparation, Acquisition and Treatment of Diffraction Data, Distortions of Diffraction Spectra, Crystallite Size, Applications, Crystal-Phase Identification, Quantitative Measurement , Wide-Angle X-Ray Diffraction and Scattering, Wide-Angle Diffraction, Wide-Angle Scattering. Problem on XRD (Calculation of d values, assigning planes, calculation of crystal parameters)

Transmission Electron Microscopy (06 L)

Instrumentation, Electron Sources, Thermionic Emission Gun, Field Emission Gun, Electromagnetic Lenses, Specimen Stage, Specimen Preparation, Pertaining, Final Thinning, Electrolytic Thinning, Ultramicrotomy, Image Modes (Mass–Density Contrast, Diffraction Contrast, Phase Contrast), Selected-Area Diffraction (SAD), Selected-Area Diffraction Characteristics.

Scanning Electron Microscopy (06 L)

Instrumentation, Optical Arrangement, Signal Detection, Detector, Probe Size and Current Contrast Formation, Electron–Specimen Interactions, Topographic Contrast, Compositional Contrast, Operational Variables, Working Distance and Aperture Size, Acceleration Voltage and Probe Current, Astigmatism, Specimen Preparation, Preparation for Topographic examination.

X-Ray Spectroscopy for Elemental Analysis (10 L)

Features of Characteristic X-Rays, Types of characteristic X-Rays, Selection Rules, Comparison of K, L, and M Series, X-Ray Fluorescence Spectrometry, Wavelength Dispersive Spectroscopy, Analysing Crystal, Wavelength Dispersive Spectra, Energy Dispersive Spectroscopy, Detector, Energy Dispersive Spectra, Advances in Energy, Dispersive Spectroscopy, XRF Working Atmosphere and Sample Preparation, Energy Dispersive Spectroscopy in Electron Microscopes, Special Features, Scanning Modes, Qualitative and Quantitative Analysis, Qualitative Analysis, Quantitative Analysis, Quantitative Analysis by X-Ray Fluorescence, Fundamental Parameter Method, Quantitative Analysis in Electron Microscopy, Numerical.

References:

1. Elaine A. Moore, Lesley E. Smart - Solid State Chemistry - an Introduction. Fourth Ed. CRC Press (2012)

2. Yang Leng, Materials Characterization-Introduction to Microscopic and Spectroscopic Methods, Second Ed.Wiley-VCH,

3. R. D. Braun, Introduction to Instrumental Analysis, Second Ed.

Course Outcome:

CO1: Students are able to understand different characterization techniques of solids

CO2: Discuss Principle of XRD, instrumentation of powder XRD, Brags law, applications of XRD for crystal structure determination, numerical problems

CO3: Apply their knowledge to the interpretation of SEM and TEM images.

CO4: Differentiate between Scanning and Transmission of electron.

CO5: Explain the basics of X-rays, the Principle of XRF, types of XRF, instrumentation, qualitative and quantitative analysis, and numerical analysis.

CO6: Applications of different characterization techniques

CHE 455 MN: Polymer Chemistry. (2 Credits, 30 L)

Introduction to Polymers **(2 L)**

Definition, history and importance of polymers, Classification: natural vs synthetic polymers

Basic concepts of monomers, degree of polymerization

Polymerization Techniques **(4 L)**

Addition vs condensation polymerization, Free radical, ionic, coordination polymerization

Step-growth vs chain-growth mechanisms

Analytical Chemistry **(6 L)**

FTIR, NMR, DSC, TGA, GPC for polymer characterization

Polymer Structure & Properties **(4 L)**

Crystallinity, glass transition temperature (Tg), melting point (Tm), Mechanical properties: tensile strength, modulus, toughness

Polymer Processing **(4 L)**

Extrusion, injection molding, blow molding, compression molding

Industrial Safety & Regulations **(2 L)**

BIS, ASTM, ISO standards for plastics

Specialty Polymers **(4 L)**

Conducting polymers, biodegradable polymers, high-performance polymers (Kevlar, PEEK)

Polymer Additives & Blends **(4 L)**

Plasticizers, stabilizers, fillers, flame retardants, Polymer alloys and composites

Course Outcomes:

Upon successful completion of this course, students will be able to:

- Explain the fundamental concepts of polymer chemistry, including classification, polymerization mechanisms, and the relationship between polymer structure and properties.
- Analyze different polymerization techniques and evaluate their suitability for the synthesis of various classes of polymers.
- Apply modern analytical techniques such as FTIR, NMR, DSC, TGA, and GPC for the characterization and quality assessment of polymers.
- Interpret the influence of polymer processing methods, additives, blends, and composites on the performance and industrial applications of polymeric materials.
- Evaluate industrial standards, safety regulations, and the applications of specialty polymers, including conducting, biodegradable, and high-performance polymers, in sustainable and advanced technologies.

Recommended References

Text Books

1. Textbook of Polymer Science, 3rd Edition, Wiley.
2. Principles of Polymerization, 4th Edition, Wiley.
3. Introduction to Polymer Science and Chemistry: A Problem-Solving Approach, CRC Press.
4. Polymer Science and Technology, 3rd Edition, Pearson.
5. Fundamentals of Polymer Engineering, CRC Press.

Reference Books

1. Polymer Chemistry, 3rd Edition, Oxford University Press.
2. Introduction to Physical Polymer Science, 4th Edition, Wiley.
3. Polymer Chemistry: An Introduction, Oxford University Press.
4. Handbook of Plastics Testing and Failure Analysis, Wiley.
5. Introduction to Polymers, 3rd Edition, CRC Press

CHE 457 MJ (P): FP/ RP/ Practical (2 Credits)

Students in this course will be required to do Fieldtrip work / Internship in relevant industries/government sectors/institutes, likes university, IIT's, IISER's, CSIR-NCL etc to gain practical training. As a prerequisite for industrial training, the department may conduct necessary lectures/workshops/seminars. The course will be run as per the guidelines of the Institute /the University and Government of Maharashtra. Most of our graduates are expected to seek employment in industries, pursue teaching careers, or establish small enterprises after obtaining their B.Sc Blended honors degree. Therefore, the following options would be provided to the students to develop skilled and competent students.

d) Hands on Training on various analytical instruments- UV-Visible Spectrometer, Fourier Transform Infrared Spectrometer, Nuclear Magnetic Resonance Spectrometer, Mass Spectrometry, Gas Chromatography, HPLC, X-Ray Diffractometer, Powder X-ray Diffractometer, Thermal Analyzer (TGA-DSC), Scanning electron microscope, Transmission electron microscope, BET Surface Analyzer, Raman Spectrometer, CHN Analyzer

Note: Analytical instruments (from above list) should be selected for Traning that should complete 120 hours training**.**

OR

e) Teacher Training Course:

1) Development of MOOCS 2) Development of Learning Management System (LMS)

OR

f) Internship in Industry or National research laboratory.

OR

f) Field trip projects that are aligned with the Subject.

A detailed report should be submitted for the evaluation of field trip work /Internship.

Learning Outcomes

Upon successful completion of the Fieldwork / Industrial Training / Internship course, students will be able to:

1. Gain practical exposure to industrial, research laboratory, academic, and field-based working environments relevant to Physics and interdisciplinary sciences.
2. Develop hands-on skills in the operation, handling, and analysis of advanced scientific and analytical instruments.
3. Understand laboratory safety procedures, experimental protocols, data acquisition, and interpretation techniques used in research and industry.
4. Apply theoretical concepts learned in coursework to real-world scientific, industrial, and technological problems.
5. Enhance problem-solving, technical communication, teamwork, and professional ethics essential for research and industry careers.

CHE 432 RP: Dissertation (04 Credits)

Following guidelines should be followed for the conduction and evaluation of research project.

1. Each student will perform project separately. • Project working hours should be 30 hours for each credit.
2. Choose a topic that aligns with your interests and career goals, but also consider its feasibility within the available resources and time frame.
3. Consult with faculty members, advisors, or mentors to identify a research area that has potential for contribution to the field of chemistry.
4. Adhere to ethical principles and standards in all aspects of your research.
5. Project report must be written systematically and presented in bound form: The project will consist of name page, certificate, content, summary of project followed by introduction, literature survey (recently published research papers must be included), experimental techniques, results and discussion, conclusions, Appendix consisting of i) references, ii) standard spectra / data if any and iii) safety precautions.
6. If student is performing project in another institute, for such a student, internal mentor must be allotted and he will be responsible for internal assessment of a student. In this case student has to obtain certificate from both external and internal mentor. Systematic record of attendance of project students must be maintained by a mentor.
7. Project will be evaluated jointly by three examiners and there will not be any practical performance during the examination. Typically, student has to present his practical work and discuss results and conclusions in details (20-30 min.) which will be followed by question-answer session (10 min). It is open type of examination.
8. Students are encouraged to participate in national and international conferences and other project competitions.

Learning Outcomes

Upon successful completion of the Dissertation course, students will be able to:

1. Develop a comprehensive understanding of key concepts, theories, and principles related to the chosen research topic.
2. Identify research problems and formulate scientifically relevant research objectives and hypotheses.
3. Acquire proficiency in experimental, computational, analytical, and theoretical research methodologies.
4. Perform literature survey and critically analyze recent scientific research publications relevant to the project work.
5. Design and execute independent research work using appropriate scientific methods and techniques.
6. Analyze, interpret, and present experimental or computational results systematically and scientifically.
7. Demonstrate scientific writing and communication skills through preparation of dissertation reports, presentations, and technical discussions.
8. Develop problem-solving ability, critical thinking, research ethics, and professional competency required for higher studies, research, industry, and entrepreneurship.
9. Present and defend research findings effectively during seminar presentations and viva-voce examinations.

Instructional Design

1. Research Supervision and Mentoring
2. Laboratory / Computational Research Work
3. Literature Review and Scientific Discussions
4. Research Seminars and Progress Presentations
5. Independent Research and Technical Report Writing

Evaluation Strategies

Component	Marks	Evaluation Authority
Literature Survey and Research Planning	10	Internal Mentor
Continuous Assessment / Research Progress	20	Internal Mentor
Experimental / Computational Work and Data Analysis	25	Internal & External Examiners
Dissertation Report Writing	20	Joint Evaluation Committee
Seminar Presentation	10	Departmental Committee
Viva-Voce Examination	15	Joint Evaluation Committee

Total Marks: 100

Guidelines for Evaluation

1. The dissertation work shall be evaluated jointly by internal and external examiners.
2. Students must maintain a regular record of research progress and attendance certified by the mentor/supervisor.
3. The dissertation report should include:

    - Title page
    - Certificate
    - Acknowledgements
    - Abstract / Summary
    - Introduction
    - Literature survey
    - Experimental / Computational methodology
    - Results and discussion
    - Conclusions
    - References
    - Appendix and safety precautions (if applicable)

4. Students shall present their research work through a seminar presentation followed by a viva-voce examination.
5. Evaluation shall be based on originality of work, scientific understanding, methodology, quality of analysis, presentation skills, and ability to answer questions effectively.
6. Participation in conferences, workshops, publications, or project competitions related to the dissertation work shall be encouraged and may be considered during internal assessment.

Savitribai Phule Pune University

Pune, India

Faculty of Science and Technology

<u>Fourth year B.Sc. Blended Honors Program</u>

Subject: **EARTH SCIENCES**

Structure and Syllabus of Fourth Year

B.Sc. Blended Honors Program in Earth Science (Geology)

(B.Sc. Honors) Degree Program

Effective from Academic year 2026 – 2027

Preamble

The syllabus has been developed through a participatory and consultative process involving extensive discussions with faculty members from the discipline of Geology, along with a careful review of existing curricula and contemporary academic requirements. In accordance with the directives of the University Grants Commission (UGC) and the framework of the National Education Policy (NEP–2020), the curriculum for the undergraduate Geology program has been designed to align with the objectives of multidisciplinary, outcome-based, and skill-oriented education.

Under the autonomous framework and in accordance with the revised guidelines issued by Savitribai Phule Pune University, the Interdisciplinary School of Science has designed the B.Sc. (Honors) Earth Science (Geology) syllabus from the academic year 2026-2027 onwards. The curriculum has been designed for review of the Board of Studies in Geology, keeping in view the contemporary relevance, emerging trends, and applications of various branches of Geology.

The process of curriculum design was initiated through a series of academic deliberations and orientation programs conducted to familiarize faculty members with the vision, principles, and implementation framework of NEP-2020. These discussions enabled effective incorporation of the key aspects of the policy, including flexibility, interdisciplinarity, experiential learning, research orientation, and outcome-based education into the revised curriculum structure.

The learning outcome-based curriculum for the B.Sc. (Earth Science) program is intended to provide students with a strong conceptual foundation in Physics while simultaneously developing analytical thinking, problem-solving abilities, experimental skills, and research aptitude. The curriculum is designed to prepare students for higher education, research, industry, and other professional opportunities in the field of science and technology.

While framing the syllabus, due consideration has been given to the UGC Learning Outcomes-based Curriculum Framework (LOCF), the recommendations of NEP–2020, and the model curriculum prescribed by Savitribai Phule Pune University to ensure academic quality, relevance, and alignment with national educational objectives.

Structure of the Syllabus with Credit Framework

Fourth Year

Sem	Course Type	Course Code: Course Name	Credit	Sub Total
VII	Major Core	**GEO 401 MJ**: Applications of Mineralogy and Crystal Chemistry **GEO 402 MJ**: Petrological processes in Earth Sciences **GEO 403 MJ:** Geodynamics & Structural Evolution of the Earth **GEO 407 MJ (P):** RP/ FP/ Practical	04 04 04 02	**14**
	Minor elective	**GEO 404 MN**: Gemmology & its applications **GEO 405 MN:** Petroleum, Coal and Hydrocarbon systems	02 02	**04**
		Select the above courses from the elective course basket given above ***OR*** Students can select From Swayam / MOOC Resources ***With prior approval of the Departmental Committee / BoS***		
	Research Method	**GEO 406 RM:** Theory of Research, Research Tools and Methods	04	**04**
		Total		**22**
VIII	Major Core	**GEO 451 MJ:** Advanced Geochemistry **GEO 452 MJ**: Disaster Management **GEO 453 MJ**: Quaternary geology **GEO 457 MJ (P):** RP/ FP/ Practical	04 04 04 02	**14**
	Minor elective	**GEO 454 MN:** Landscape Analyses and Remote sensing **GEO 455 MN:** Natural Resource Management.	02 02	**04**
		Select any course from the elective course basket given above ***OR*** Students can select From Swayam / MOOC Resources ***With prior approval of the Departmental Committee / BoS***		
	Res. Project/ FP	GEO 432 RP: Dissertation	04	**04**
		Total		**22**

GEO 401 MJ: Applications of Mineralogy and Crystal Chemistry (4 Credits, 60 L)

UNIT I: Fundamentals of Crystal Chemistry and Mineral Structures

Teaching Hours: 15

Topics

1. Principles of crystal chemistry
   - Atomic structure and bonding in minerals
   - Ionic radii and coordination number
   - Pauling's rules and crystal stability
2. Crystal structures
   - Structures of silicates and non-silicates
   - Isomorphism, polymorphism, and solid solution
   - Order–disorder phenomena in minerals
3. Relationship between crystal structure and physical properties
   - Cleavage, hardness, density, optical properties
   - Electrical and magnetic properties of minerals
4. Defects in crystals
   - Point defects, line defects, and surface defects
   - Effect of defects on mineral properties

UNIT II: Optical Mineralogy and Analytical Techniques

Teaching Hours: 15

Topics

1. Optical properties of minerals
   - Refraction, birefringence, pleochroism
   - Interference colors and extinction
2. Polarizing microscope techniques
   - Identification of minerals in thin sections
   - Optical characteristics of common rock-forming minerals
3. X-ray crystallography
   - Principles of X-ray diffraction (XRD)
   - Bragg's Law and crystal structure determination
4. Advanced analytical methods
   - Electron microprobe analysis (EPMA)
   - Scanning electron microscopy (SEM)

- Spectroscopic techniques in mineralogy

UNIT III: Applications in Petrology, Economic Geology, and Industry

Teaching Hours: 15

Topics

1. Mineralogy in igneous and metamorphic petrology
    - Mineral stability and phase relations
    - Geothermometry and geobarometry
2. Ore mineralogy
    - Mineral associations in ore deposits
    - Crystal chemistry of sulfides and oxides
3. Industrial applications of minerals
    - Clay minerals, ceramics, refractories, cement
    - Gemstones and ornamental minerals
4. Mineral exploration techniques
    - Indicator minerals
    - Remote sensing and geochemical applications

UNIT IV: Modern Applications of Mineralogy

Teaching Hours: 15

Topics

1. Environmental mineralogy
    - Clay–water interactions
    - Heavy metal adsorption and pollution control
    - Asbestos and health hazards
2. Biomineralization and medical mineralogy
    - Formation of shells, bones, and teeth
    - Minerals in medical applications
3. Nanomineralogy and material science
    - Nanocrystals and nanomaterials
    - Functional minerals and advanced materials
4. Recent developments in mineralogy and crystal chemistry
    - Computational mineralogy
    - Planetary mineralogy and extraterrestrial materials

Course Objectives

The course aims to:

- Develop advanced understanding of mineralogy and crystal chemistry.
- Explain the relationship between crystal structure, chemical composition, and mineral properties.
- Introduce modern analytical techniques used in mineralogical investigations.
- Apply mineralogical and crystal chemical principles in geology, industry, environmental science, and material science.

Learning Outcomes

After completion of the course, students will be able to:

1. Explain crystal chemical principles governing mineral structures.
2. Identify minerals using optical and instrumental techniques.
3. Apply mineralogical knowledge in petrology, ore geology, and industry.
4. Evaluate environmental and technological applications of minerals.
5. Interpret mineralogical data using modern analytical tools.

References

1. Introduction to Mineralogy – William D. Nesse
2. Manual of Mineral Science – Cornelis Klein & Barbara Dutrow
3. Principles of Mineralogy – Dexter Perkins
4. Optical Mineralogy – D. Shelley
5. X-ray Diffraction Procedures – Klug & Alexander
6. Crystal Chemistry – C. W. Burnham

GEO 402 MJ: Petrological processes in Earth Sciences (4 Credits, 60 L)

UNIT I: Fundamentals of Igneous Processes and Mantle Melting

Teaching Hours: 15

Topics

1. Internal structure and composition of the Earth
   - Crust, mantle, and core
   - Physical and chemical characteristics of the mantle
2. Mantle dynamics and convection
   - Mantle convection currents
   - Heat transfer mechanisms within the Earth
   - Mantle plumes and hotspot activity
3. Generation of magma
   - Partial melting and magma genesis

- Role of pressure, temperature, and volatiles
- Decompression melting and flux melting

4. Magma evolution
    - Fractional crystallization
    - Assimilation and magma mixing
    - Bowen’s reaction series

UNIT II: Igneous Petrology and Tectonic Settings

Teaching Hours: 15

Topics

1. Classification of igneous rocks
    - Ultramafic, mafic, intermediate, and felsic rocks
    - Modal and chemical classification
2. Oceanic and continental magmatism
    - Mid-ocean ridge basalts (MORB) Island arc volcanism
    - Continental flood basalts
3. Mantle geochemistry
    - Trace elements and rare earth elements (REE)
    - Isotopic signatures of mantle reservoirs
    - Primitive mantle and mantle heterogeneity
4. Igneous activity and plate tectonics
    - Divergent, convergent, and intraplate settings
    - Ophiolites and mantle xenoliths

UNIT III: Metamorphic Processes and Deep Crustal Dynamics

Teaching Hours: 15

Topics

1. Fundamentals of metamorphism
    - Agents and types of metamorphism
    - Metamorphic grade and facies
2. Metamorphic textures and structures
    - Foliation and lineation
    - Recrystallization and reaction textures
3. Metamorphic facies and tectonic environments
    - Greenschist, amphibolite, granulite, and eclogite facies

    - Subduction zone metamorphism
    - Regional and contact metamorphism
4. Crust–mantle interaction
    - Crustal thickening and mountain building
    - High-pressure metamorphism
    - Anatexis and migmatite formation

UNIT IV: Modern Approaches to Mantle Dynamics and Petrological Applications

Teaching Hours: 15

Topics

1. Geophysical approaches to mantle studies
    - Seismic tomography
    - Mantle discontinuities and lithosphere–asthenosphere boundary

2. Experimental and computational petrology
    - High-pressure and high-temperature experiments
    - Thermodynamic modeling of mantle processes
3. Mantle dynamics and global tectonics
    - Superplumes and supercontinent cycles
    - Mantle evolution through geological time
4. Applied and recent developments
    - Mantle-derived ore deposits
    - Planetary mantle processes
    - Remote sensing and GIS applications in petrology

Course Objectives

The course aims to:

- Develop understanding of igneous and metamorphic processes operating within the Earth.
- Explain mantle dynamics and their role in crustal evolution and tectonics.
- Introduce petrological, geochemical, and geophysical approaches used in studying mantle-derived rocks.
- Understand the relationship between magmatism, metamorphism, and plate tectonics.

Learning Outcomes

After completion of the course, students will be able to:

1. Explain mantle dynamics and magma generation processes.
2. Identify and classify igneous and metamorphic rocks.
3. Interpret tectonic settings using petrological and geochemical evidence.
4. Understand crust–mantle interactions and metamorphic evolution.
5. Apply modern analytical and computational methods in petrology and mantle studies.

Suggested Books and References

1. Principles of Igneous and Metamorphic Petrology – Anthony Philpotts & Jay Ague
2. Igneous and Metamorphic Petrology – Turner & Verhoogen
3. Mantle Dynamics – David Bercovici
4. Introduction to Mantle Dynamics – Geoffrey F. Davies
5. Metamorphic Petrology – Bruce Yardley
6. Using Geochemical Data – Hugh Rollinson
7. Earth Materials – Klein & Philpotts

GEO 403 MN: Geodynamics and Structural Evolution of the Earth(2 Credit, 30L)

UNIT I: Fundamentals of Geodynamics and Structural Geology and Deformation Processes

Teaching Hours: 10

Topics

1. Fundamentals of structural geology
   - Structural elements and geological structures
   - Attitude measurements and stereographic projections
2. Folds and folding mechanisms
   - Classification and geometry of folds
   - Mechanics of folding and fold development
3. Faults and fractures
   - Classification of faults
   - Fault mechanics and tectonic significance
   - Joints and shear zones
4. Ductile deformation structures
   - Cleavage, foliation, and lineation
   - Boudinage and mylonites
5. Structural analysis and tectonic interpretation

    - Structural mapping and cross-sections
    - Balanced sections and kinematic analysis
6. Principles of geodynamics
    - Heat flow and geothermal gradient
    - Mantle convection and Earth's energy sources
    - Isostasy and gravity anomalies
7. Plate tectonics and global geodynamics
    - Continental drift and seafloor spreading
    - Plate boundaries and plate motions
    - Wilson cycle and supercontinent evolution
8. Geophysical evidence for Earth dynamics
    - Seismology and Earth structure
    - Paleomagnetism and geomagnetism
    - Geodetic and satellite-based observations
9. Earth deformation and stress
    - Stress, strain, and rheology of rocks
    - Brittle and ductile deformation

Practical/Assignments

- Interpretation of tectonic and geophysical maps
- Analysis of plate motion data
- Exercises on stress and strain calculations

UNIT II: Orogeny, Crustal Evolution, and Tectonic Processes

Teaching Hours: 10

Topics

1. Orogenic processes and mountain building
    - Types of orogenies
    - Continental collision and subduction zones
    - Accretionary prisms and foreland basins
2. Crustal evolution through geological time
    - Growth and differentiation of continental crust
    - Cratons, shields, and mobile belts
3. Extensional and compressional tectonics

   - Rift systems and basin evolution
   - Thrust tectonics and nappe structures
4. Metamorphism and tectonics
   - Regional metamorphism and deformation
   - P–T–t paths and tectonometamorphic evolution
5. Tectonics of India
   - Himalayan orogeny
   - Peninsular India and major tectonic provinces

Practical/Assignments

- Case studies of major orogenic belts
- Interpretation of tectonic maps and sections
- Analysis of tectonic evolution models

UNIT III: Modern Geodynamics and Applied Structural Geology

Teaching Hours: 10

Topics

1. Mantle dynamics and lithosphere interaction
   - Mantle plumes and hotspot volcanism
   - Lithosphere–asthenosphere interaction
   - Mantle tomography
2. Earthquake tectonics and active deformation
   - Earthquake mechanisms and fault movement
   - Seismic hazards and neotectonics
   - Active tectonic studies
3. Geodynamics and natural resources
   - Structural controls on mineralization
   - Petroleum traps and basin tectonics
   - Engineering geological applications
4. Modern tools and techniques
   - Remote sensing and GIS in structural geology
   - GPS and geodetic studies
   - Numerical and analogue modelling of tectonic processes
5. Recent advances in Earth dynamics
   - Plate reconstruction models
   - Planetary tectonics

- Future directions in geodynamic research

Practical/Assignments

- Interpretation of satellite imagery and tectonic features
- Seismic data and fault analysis
- Seminar on recent developments in geodynamics

Suggested Teaching Methodology

- Classroom lectures with diagrams and animations
- Geological map and structural data interpretation
- Laboratory demonstrations and modelling exercises
- Field visits to structurally significant geological areas
- Student seminars and project work

Learning Outcomes

After completion of the course, students will be able to:

1. Explain the geodynamic processes operating within the Earth.
2. Interpret structural features and tectonic evolution of geological terrains.
3. Analyze deformation processes using structural and geophysical data.
4. Understand crust–mantle interactions and Earth evolution.
5. Apply structural and geodynamic concepts in resource exploration and hazard assessment.

Suggested Books and References

1. Structural Geology – Haakon Fossen
2. The Dynamic Earth – Skinner & Porter
3. Geodynamics – Turcotte & Schubert
4. Principles of Structural Geology – John Suppe
5. Global Tectonics – Kearey, Klepeis & Vine
6. Tectonics – Moores & Twiss
7. Introduction to Geophysics – Harry H. Hess

GEO 404 MN: Gemmology and its Applications

Unit I: Introduction to Gemmology (6 Hours)

- Definition and scope of gemmology
- Historical development of gemstones
- Formation of gemstones
- Geological environments of gemstone deposits
- Classification of gemstones
  - Precious and semi-precious gemstones
  - Organic gemstones
  - Gem minerals and gem rocks

Unit II: Gemstone Identification Techniques (8 Hours)

- Principles of gemstone identification
- Common inclusions in gemstones
- Identification of important gemstones:

Unit III: Gemstone Enhancement and Applications (8 Hours)

- Synthetic gemstones
- Artificial and imitation gemstones
- Common gemstone treatments:
- Gem grading and certification
- Ethical sourcing and responsible mining
- Gemstone industry in India
- Applications of gemstones:

GEO 405 MN: Petroleum, Coal and Hydrocarbon systems (2 Credit, 30L)

GEO 405 MN: Petroleum, Coal and Hydrocarbon Systems

UNIT I: Petroleum Geology and Hydrocarbon Systems

Teaching Hours: 15

Topics

1. Introduction to petroleum geology
   - Composition and properties of petroleum and natural gas
   - Origin and migration of hydrocarbons
   - Organic matter and kerogen types
2. Elements of petroleum systems
   - Source rocks
   - Reservoir rocks and porosity
   - Cap rocks and traps

    - Structural and stratigraphic traps
3. Hydrocarbon generation and accumulation
    - Thermal maturation and catagenesis
    - Migration pathways and accumulation mechanisms
4. Petroleum exploration techniques
    - Geological and geophysical methods
    - Seismic exploration and well logging
    - Offshore and onshore exploration
5. Environmental aspects of petroleum extraction
    - Oil spills and pollution
    - Sustainable management of hydrocarbon resources

Practical/Assignments

- Identification of petroleum-bearing rocks
- Interpretation of seismic and well-log data
- Case studies of major petroleum basins

UNIT II: Coal Geology and Unconventional Hydrocarbon Resources

Teaching Hours: 15

Topics

1. Origin and formation of coal
    - Peat formation and coalification
    - Rank and grade of coal
    - Physical and chemical properties of coal
2. Classification and types of coal
    - Lignite, bituminous, and anthracite coal
    - Macerals and coal petrography
3. Coal-bearing basins and economic significance
    - Gondwana coal deposits of India
    - Coal mining methods and utilization
4. Unconventional hydrocarbon resources
    - Coal bed methane (CBM)
    - Shale gas and shale oil
    - Gas hydrates and tar sands
5. Environmental and energy perspectives
    - Environmental impacts of coal mining

- Clean coal technologies
- Future of fossil fuels and energy transition

Practical/Assignments

- Megascopic study of coal samples
- Coal rank determination exercises
- Seminar on unconventional hydrocarbon resources

Suggested Teaching Methodology

- Classroom lectures with audiovisual aids
- Laboratory study of coal and petroleum samples
- Interpretation of geological and geophysical data
- Field visits to coal mines or petroleum exploration sites
- Student seminars and assignments

Course Objectives

The course aims to:

- Introduce the origin, occurrence, and classification of fossil fuels.
- Explain the geological processes involved in the formation of petroleum, coal, and natural gas.
- Develop understanding of hydrocarbon systems and exploration techniques.
- Highlight the economic and environmental significance of fossil fuel resources.

Learning Outcomes

After completion of the course, students will be able to:

1. Explain the origin and occurrence of petroleum, coal, and natural gas.
2. Describe the components of hydrocarbon systems.
3. Understand exploration and extraction techniques of fossil fuels.
4. Evaluate the economic importance and environmental impacts of hydrocarbon resources.
5. Identify conventional and unconventional energy resources.

Suggested Books and References

1. Elements of Petroleum Geology – Richard C. Selley
2. Petroleum Geoscience – Gluyas & Swarbrick
3. Coal Geology – Larry Thomas
4. Introduction to Petroleum Geology – Bhaskar Rao

5. Organic Geochemistry – J.M. Hunt
6. Applied Coal Petrology – International Committee for Coal and Organic Petrology
7. Energy Resources and Earth Science – Gareth Ll. Jones

GEO 406 RM: Theory of research, research tools and methods (4 Credits, 60 L)

Fundamentals of Research Methodology (10 L)

Meaning, objectives, and significance of research, Types of research: basic, applied, experimental, analytical, and computational, Identification and formulation of research problems, Hypothesis formulation and testing, Research planning and research design, Interdisciplinary and multidisciplinary research approaches.

Literature Survey and Scientific Documentation (10 L)

Literature survey techniques, Use of scientific databases: Scopus, Web of Science, Google Scholar, arXiv, INSPIRE, Reference management software (Zotero, Mendeley, EndNote), presentation softwares (MS Powerpoint, MS eord, LaTex)

Scientific Communication and Research Practices (10 L)

Scientific communication and technical writing of evaluation report and thesis writing. Intellectual Property Rights (IPR), patents, copyrights, and trademarks Introduction to innovation and entrepreneurship in scientific research

Research Tools and Data Analysis (10 L)

Experimental and computational tools for research, Data acquisition and data processing techniques, Error analysis and uncertainty estimation, Graph plotting and curve fitting Statistical analysis and interpretation of data, Use of software tools (Origin, MATLAB/Python basics, Excel, gnuplot).

References

1. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International, 1990
2. B. L. Garg, R. Karadia, F. Agarwal and U. K. Agarwal, An introduction to Research Methodology, RBSA Publishers, 2002
3. S. M. Coley and C. A. Scheinberg, Proposal Writing, Sage Publications, 1990.
4. Research Methodology by Best and Kahn, PHI Limited.

5. Research Methodology by R. Kumar, A Step-By-Step Guide for Beginners, Pearson Education, Delhi (2006).
6. Fundamentals of modern statistical methods by Rand R.wilcox.
7. Power Analysis for Experimental Research A Practical Guide for the Biological, Medical and social Sciences by R. Barker Bausell, Yi-Fang Li Cambridge University Press.
8. Design of Experience: Statistical Principles of Research Design and Analysis, by Robert O. Kuehl Brooks/cole.
9. Panneerselvam R., Research Methodology, Prentice Hall Of India, New Delhi,2004
10. Design & Analysis of Experiments by D. C. Montgomery, 5th Ed., Wiley India (2007).

Course outcomes:

CO1: Develop a comprehensive understanding of different research methodologies and their applications in mathematics.

CO2: Cultivate critical thinking and analytical skills necessary for identifying research problems and formulating research questions.

CO3: Provide practical experience in designing experiments, collecting and analyzing data, and interpreting research results.

CO4: Foster effective communication skills for presenting research findings orally and in written form.

CO5: Promote ethical research practices and awareness of responsible conduct in mathematical research

CO5; Develop problem solving ability.

GEO 407 FP: Fieldwork/Industrial training/ Researcgh project/ Practicals: (2 Credits)

Students in this course will be required to do Fieldtrip/Internship in relevant industries/government sectors/institutes, likes university, IIT's, IISER's, CSIR-NCL etc to gain practical training. As a prerequisite for industrial training, the department may conduct necessary lectures/workshops/seminars. The course will be run as per the guidelines of the Institute /the University and Government of Maharashtra. Most of our graduates are expected to seek employment in industries, pursue teaching careers, or establish small enterprises after obtaining their B.Sc Blended honors degree. Therefore, the following options would be provided to the students to develop skilled and competent students.

a) Hands on Training on various analytical instruments- UV-Visible Spectrometer, Fourier Transform Infrared Spectrometer, Nuclear Magnetic Resonance Spectrometer, Mass Spectrometry, Gas Chromatography, HPLC, X-Ray Diffractometer, Powder X-ray Diffractometer, Thermal Analyzer (TGA-DSC), Scanning electron microscope, Transmission electron microscope, BET Surface Analyzer, Raman Spectrometer, CHN Analyzer

Note: Analytical instruments (from above list) should be selected for Traning that should complete 120 hours training**.**

OR

b) Teacher Training Course:

1) Development of MOOCS 2) Development of Learning Management System (LMS)

OR

c) Internship in Industry or National research laboratory.

OR

d) To develop Entrepreneurship, production of the following items, including packaging

1) Dye

2) Acids, caustic soda

3) Fire Extinguisher

4) Fertilizers

5) Any other industry material

OR

e) Field trip projects that are aligned with the Subject.

A detailed report should be submitted for the evaluation of field trip work /Internship.

SEMESTER VIII

GEO 451 MJ: Advanced Geochemistry (4 Credit, 60L)

UNIT I: Fundamentals of Geochemistry in Igneous and Metamorphic Systems

Teaching Hours: 15

Topics

1. Introduction to petrological geochemistry
   - Scope and significance in Earth Sciences
   - Composition of crust, mantle, and major rock-forming minerals
2. Crystal chemistry and elemental behavior
   - Ionic substitution and partition coefficients
   - Goldschmidt classification of elements
   - Compatible and incompatible elements
3. Thermodynamics of petrological systems
   - Laws of thermodynamics
   - Gibbs free energy and equilibrium
   - Phase equilibria in igneous and metamorphic rocks
4. Geochemistry of silicate melts and metamorphic fluids
   - Melt composition and evolution
   - Fluid–rock interaction and metasomatism
   - Role of volatiles in petrogenesis
5. Trace elements and rare earth elements (REE)
   - Distribution of trace elements in minerals and melts
   - REE patterns and petrogenetic significance

Practical/Assignments

- Calculation of partition coefficients
- Interpretation of REE and spider diagrams
- Study of phase equilibrium diagrams

UNIT II: Geochemistry of Igneous Processes and Magmatic Modelling

Teaching Hours: 15

Topics

1. Magma generation and evolution
   - Partial melting and magma genesis

- Fractional crystallization and crystal settling
- Assimilation and magma mixing

2. Geochemical characteristics of igneous rocks
    - Major and trace element geochemistry
    - Classification and tectonic discrimination diagrams
    - Geochemistry of MORB, OIB, and arc magmas
3. Isotope geochemistry in igneous petrology
    - Radiogenic isotopes: Sr, Nd, Pb isotopes
    - Mantle reservoirs and crustal contamination
    - Isotopic evolution of magmatic systems
4. Geochemical modelling of magmatic processes
    - Batch melting and fractional melting models
    - Rayleigh fractionation models
    - Mass balance calculations in igneous systems
5. Geochemical analytical techniques
    - XRF, ICP-MS, and electron microprobe analysis
    - Data interpretation and analytical precision

Practical/Assignments

- Construction of variation diagrams (Harker diagrams)
- Geochemical modelling of magma evolution
- Interpretation of isotopic datasets

UNIT III: Geochemistry of Metamorphic Processes and Metamorphic Modelling

Teaching Hours: 15

Topics

1. Geochemistry of metamorphism
    - Metamorphic reactions and mineral stability
    - Element mobility during metamorphism
    - Metasomatism and fluid interaction
2. Metamorphic facies and geochemical signatures
    - Greenschist, amphibolite, granulite, and eclogite facies
    - Index minerals and P–T conditions
    - Geochemical indicators of metamorphic grade
3. Thermobarometry and geothermometry
    - Principles and applications

    - Mineral equilibria and exchange reactions
    - Construction of P–T paths
4. Geochemical modelling in metamorphic petrology
    - Equilibrium assemblage diagrams
    - Phase diagrams and pseudosections
    - Thermodynamic modelling approaches
5. Isotope geochemistry in metamorphism
    - Stable isotopes (O, C, H) in metamorphic systems
    - Geochronology and metamorphic evolution

Practical/Assignments

- Construction and interpretation of metamorphic facies diagrams
- P–T estimation exercises
- Study of metamorphic reaction textures and geochemical trends

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UNIT IV: Applied Petrological Geochemistry and Modern Developments

Teaching Hours: 15

Topics

1. Crust–mantle interaction and tectonic setting
    - Subduction zone geochemistry
    - Continental crust evolution
    - Mantle metasomatism and crustal recycling
2. Experimental petrology and modelling
    - High-pressure and high-temperature experiments
    - Experimental simulation of petrological processes
3. Computational petrology and geochemical software
    - Introduction to petrological modelling software
    - Geochemical databases and digital interpretation
    - Statistical analysis of petrological data
4. Applied geochemistry in mineral exploration
    - Pathfinder elements and alteration zones
    - Ore-forming processes related to igneous and metamorphic activity
5. Recent advances in petrological geochemistry
    - Planetary petrology and meteorites
    - Nanogeochemistry and microanalytical techniques
    - Geochemistry and sustainable Earth resource studies

Practical/Assignments

- Interpretation of petrological geochemical datasets
- Demonstration of modelling software and analytical instruments
- Seminar on recent advances in petrological geochemistry

Course Objectives

The course aims to:

- Develop advanced understanding of geochemical principles related to igneous and metamorphic petrology.
- Explain elemental distribution, magma evolution, and metamorphic reactions using geochemical approaches.
- Introduce geochemical modelling techniques used in petrological studies.
- Familiarize students with analytical and computational methods for interpreting igneous and metamorphic processes.

Learning Outcomes

After completion of the course, students will be able to:

6. Explain the geodynamic processes operating within the Earth.
7. Interpret structural features and tectonic evolution of geological terrains.
8. Analyze deformation processes using structural and geophysical data.
9. Understand crust–mantle interactions and Earth evolution.
10. Apply structural and geodynamic concepts in resource exploration and hazard assessment.

Suggested Books and References

8. Structural Geology – Haakon Fossen
9. The Dynamic Earth – Skinner & Porter
10. Geodynamics – Turcotte & Schubert
11. Principles of Structural Geology – John Suppe
12. Global Tectonics – Kearey, Klepeis & Vine
13. Tectonics – Moores & Twiss
14. Introduction to Geophysics – Harry H. Hess

GEO 452 MJ: Disaster Management **(4 Credit, 60L)**

UNIT I: Introduction to Disaster Management

(15 Hours)

Topics

- Concept and definition of disaster
- Hazard, vulnerability, risk, capacity, and resilience
- Types of disasters:
  - Natural disasters
    - Earthquakes
    - Floods
    - Cyclones
    - Droughts
    - Landslides
    - Tsunami
  - Anthropogenic disasters
    - Industrial accidents
    - Nuclear disasters
    - Chemical hazards
    - Fire hazards
    - Biological disasters
- Disaster management cycle
  - Prevention
  - Mitigation
  - Preparedness
  - Response
  - Recovery
  - Rehabilitation
- Disaster trends at global and national levels

UNIT II: Disaster Risk Assessment and Mitigation

(15 Hours)

Topics

- Disaster risk assessment
- Hazard zonation and vulnerability analysis
- Environmental degradation and disasters

- Climate change and disaster risks
- Structural and non-structural mitigation measures
- Early warning systems
- Remote sensing and GIS applications in disaster management
- Community participation in disaster mitigation
- Sustainable development and disaster risk reduction

UNIT III: Disaster Preparedness, Response, and Recovery

(15 Hours)

Topics

- Disaster preparedness planning
- Emergency operations and response mechanisms
- Search and rescue operations
- First aid and medical preparedness
- Relief management and logistics
- Rehabilitation and reconstruction
- Psychological impacts of disasters
- Role of media and communication during disasters
- Role of NGOs, civil society, and local communities
- Case studies of major disasters in India and the world

UNIT IV: Policies, Institutions, and Community-Based Disaster Management

(15 Hours)

Topics

- Disaster management policies in India
- Disaster Management Act, 2005
- National Disaster Management Authority (NDMA)
- State and District Disaster Management Authorities
- International organizations and frameworks:
    - UNDRR
    - Sendai Framework for Disaster Risk Reduction
    - Red Cross and Red Crescent Movement
- Community-based disaster management (CBDM)
- Disaster education and awareness
- School and hospital safety programs

- Gender and disaster management
- Indigenous knowledge in disaster management

Course Objectives

The course aims to:

1. Introduce students to the concepts, principles, and approaches of disaster management.
2. Develop understanding of natural and anthropogenic disasters and their impacts on society and environment.
3. Familiarize students with disaster preparedness, mitigation, response, and recovery strategies.
4. Build skills related to risk assessment, emergency planning, and community resilience.
5. Encourage practical understanding of disaster management policies and institutional frameworks.

Learning Outcomes

Students will:

- Understand disaster management policies and legal frameworks.
- Explain institutional roles in disaster management.
- Develop awareness of community-based approaches.
- Understand the nature, causes, and classification of disasters.
- Analyze disaster risks and vulnerabilities in different environmental settings.
- Apply disaster preparedness and mitigation techniques.
- Explain institutional and policy frameworks related to disaster management.
- Develop community-based disaster management and resilience strategies.

Suggested Practical/Field Activities

1. Preparation of hazard maps for local areas.
2. Mock drill and evacuation planning.
3. Survey of disaster-prone regions.
4. Community awareness campaign.
5. Visit to disaster management authority or relief center.
6. Case study report on a recent disaster event.

Suggested Readings

1. Singh, R.B. – Disaster Management.
2. Coppola, D.P. – Introduction to International Disaster Management.
3. Gupta, H.K. – Disaster Management.

4. Alexander, D. – Principles of Emergency Planning and Management.
5. NDMA Guidelines and Reports.
6. Government of India – Disaster Management Act, 2005.
7. Wisner, B. et al. – At Risk: Natural Hazards, People's Vulnerability and Disasters.

GEO 453 MJ: Quaternary Geology 4 credit (60 Lecture)

Unit 1: Introduction to the Quaternary (1 Credit)

- Definition, subdivisions (Pleistocene, Holocene, and the Anthropocene).
- Quaternary time scales and chronostratigraphy.
- Geological and biological proxy records (ice cores, marine sediments, tree rings, pollen, and speleothems).

Unit 2: Quaternary Climate Change (1 Credit)

- Causes of Quaternary climate shifts.
- Astronomical forcing → Milankovitch cycles (eccentricity, obliquity, precession).
- Glacial and interglacial cycles.
- Eustatic and isostatic sea-level changes.

Unit 3: Glacial and Non-Glacial Geomorphology (1 Credit)

- Glacial landforms: moraines, drumlins, eskers, and glacial lakes.
- Periglacial landforms: permafrost, patterned ground, and loess deposits.
- Quaternary deposits in the Indian subcontinent (fluvial terraces, coastal deposits, and aeolian sands). [1, 2, 3, 4]

Unit 4: Quaternary Dating Methods & Neotectonics (1 Credit)

- Absolute dating techniques: Radiocarbon (^{14}C), Luminescence (OSL/TL), and cosmogenic radionuclides (^{10}Be).
- Relative dating techniques: Tephrochronology, paleomagnetism, and dendrochronology.
- Neotectonics and active faulting during the Quaternary period.
- Quaternary stratigraphy and its applications to environmental and hazard studies.

Course Objectives

- The primary goals of this course are to enable students to:
- Understand the unique climatic, tectonic, and biological events of the last 2.58 million years.
- Master the specialized dating methods and proxy tools used to reconstruct past environments.
- Analyze the driving mechanisms of glacial-interglacial cycles and global climate change.

- Evaluate human-environment interactions and the geological footprint of the Anthropocene.

  Course Learning Outcomes (CLOs)

  Upon successful completion of this course, students will be able to:

- Differentiate Quaternary stratigraphic units using global chronostratigraphic standards.
- Select appropriate geochronological dating techniques for various Quaternary materials.
- Interpret paleoclimate proxy data from ice cores, marine sediments, and terrestrial records.
- Map landforms generated by glacial, fluvial, and aeolian processes during the Quaternary.
- Predict future climate trends by analyzing historical baseline data.

  References:

- Paleoclimatology: Reconstructing Climates of the Quaternary by Raymond S. Bradley
- Quaternary Geology: A Stratigraphic Framework for Multidisciplinary Work by **D.Q. Bowen**
- Quaternary Climate Dynamics: Integrating Paleoclimate Data, Modeling and Theory by **Palacio et al.**

GEO 454 MN : Landscape Analysis and Remote Sensing (2 Credits, 30 L)

UNIT I: Fundamentals of Landscape Analysis and Geomorphology

Teaching Hours: 15

Topics

1. Introduction to landscape analysis
   - Concept and scope of landscape studies
   - Components of landscapes and geomorphic systems
2. Geomorphic processes and landform development
   - Weathering, erosion, transportation, and deposition
   - Fluvial, aeolian, glacial, coastal, and tectonic landscapes
3. Morphometric analysis
   - Drainage basin characteristics
   - Slope, relief, and watershed analysis
   - Digital Elevation Models (DEM) and terrain analysis
4. Landscape evolution and environmental changes
   - Geomorphic cycles and dynamic equilibrium
   - Human impact on landscapes
   - Land degradation and conservation

5. Applications of landscape analysis
    - Natural resource management
    - Watershed management
    - Hazard zonation and environmental planning

Practical/Assignments

- Interpretation of topographic maps
- Morphometric analysis of drainage basins
- Preparation of slope and relief maps

UNIT II: Remote Sensing and Geospatial Applications

Teaching Hours: 15

Topics

Fundamentals of remote sensing

- Principles and electromagnetic spectrum
- Types of remote sensing: passive and active
- Resolution concepts (spatial, spectral, temporal, radiometric)

2. Platforms and sensors
    - Aerial photography and satellite remote sensing
    - Sensors used in geological and environmental studies
    - Indian remote sensing satellites and applications
3. Image interpretation and digital analysis
    - Visual image interpretation techniques
    - Digital image processing and classification
    - False color composites (FCC) and spectral signatures
4. Geographic Information System (GIS)
    - Components and functions of GIS
    - Spatial data models and map overlay analysis
    - Integration of GIS and remote sensing
5. Applications in Earth and Environmental Sciences
    - Geological mapping and mineral exploration
    - Land use/land cover studies
    - Disaster management and environmental monitoring

Practical/Assignments

- Interpretation of satellite imagery and aerial photographs
- Basic GIS mapping exercises

- Land use/land cover classification project
- Seminar on recent advances in geospatial technologies

Course Objectives

The course aims to:

- Introduce concepts of landscape analysis and geomorphic interpretation.
- Develop understanding of remote sensing principles and applications in Earth Sciences.
- Explain the use of aerial photographs, satellite imagery, and GIS techniques in landscape studies.
- Familiarize students with modern geospatial technologies for environmental and geological investigations.

Learning Outcomes

After completion of the course, students will be able to:

1. Explain geomorphic processes and landscape evolution.
2. Analyze landscapes using morphometric and geospatial techniques.
3. Understand principles and applications of remote sensing.
4. Interpret aerial photographs and satellite imagery.
5. Apply GIS and remote sensing in geological and environmental studies.

Suggested Books and References

1. Remote Sensing and Image Interpretation – Lillesand & Kiefer
2. Principles of Geographical Information Systems – Peter A. Burrough
3. Geomorphology – Savindra Singh
4. Fundamentals of Remote Sensing – George Joseph
5. Remote Sensing Geology – R.P. Gupta
6. Geomorphology and Environment – Andrew Goudie
7. GIS Fundamentals – Paul Bolstad

GEO 455 MN: Natural Resource Management (2 Credit, 30L)

UNIT I: Fundamentals of Natural Resources and Environmental Management

Teaching Hours: 15

Topics

1. Introduction to natural resources
    - Definition, classification, and distribution of resources

- Renewable and non-renewable resources

2. Land and soil resource management
    - Soil formation and degradation
    - Soil conservation and reclamation methods
    - Sustainable land-use planning
3. Water resource management
    - Surface and groundwater resources
    - Watershed management and rainwater harvesting
    - Water conservation techniques
4. Forest and biodiversity resources
    - Forest ecosystems and conservation
    - Biodiversity and ecosystem services
    - Protected areas and wildlife conservation
5. Environmental management principles
    - Environmental impact assessment (EIA)
    - Sustainable development and resource conservation policies
    - Climate change and environmental challenges

Practical/Assignments

- Preparation of resource distribution maps
- Soil and water conservation case studies
- Environmental impact assessment exercises

UNIT II: Energy, Mineral Resources, and Sustainable Resource Utilization

Teaching Hours: 15

Topics

1. Mineral resource management
    - Classification and distribution of mineral resources
    - Mining methods and environmental impacts
    - Sustainable mining practices and reclamation
2. Energy resources and management
    - Conventional and non-conventional energy resources
    - Renewable energy: solar, wind, hydro, geothermal, and biomass
    - Energy conservation and energy security
3. Resource economics and policy

- Resource utilization and economic development
    - National resource policies and legislation
    - Community participation in resource management

4. Modern tools in resource management
    - GIS and remote sensing applications
    - Resource mapping and monitoring
    - Geospatial techniques in environmental management

Sustainable resource management strategies

- Circular economy and waste management
- Integrated natural resource management (INRM)
- Future challenges in resource sustainability

Practical/Assignments

- Mineral and energy resource mapping exercises
- GIS-based resource analysis
- Seminar on sustainable development and resource conservation

Course Objectives

The course aims to:

- Introduce the concepts and principles of natural resource management.
- Develop understanding of the sustainable utilization and conservation of natural resources.
- Explain environmental challenges related to resource exploitation and management.
- Familiarize students with modern approaches and policies for resource conservation and sustainable development.

Learning Outcomes

After completion of the course, students will be able to:

1. Understand the classification and importance of natural resources.
2. Explain methods of conservation and sustainable utilization of resources.
3. Analyze environmental impacts associated with resource exploitation.
4. Apply geospatial and management tools in resource planning.
5. Evaluate policies and strategies related to sustainable development and resource management.

Suggested Books and References

1. Natural Resource Conservation and Management – Daniel D. Chiras

2. Environmental Science and Engineering – P. Anandan
3. Natural Resource Management – B. Mohapatra
4. Introduction to Environmental Management – Theodore & Theodore
5. Resource and Environmental Economics – Roger Perman
6. Remote Sensing and GIS – Basudeb Bhatta
7. Sustainable Development – William M. Lafferty

GEO 432 RP: Dissertation (04 Credits)

Following guidelines should be followed for the conduction and evaluation of research project.

• Each student will perform project separately. • Project working hours should be 30 hours for each credit.

• Choose a topic that aligns with your interests and career goals, but also consider its feasibility within the available resources and time frame.

• Consult with faculty members, advisors, or mentors to identify a research area that has potential for contribution to the field of chemistry.

• Adhere to ethical principles and standards in all aspects of your research.

• Project report must be written systematically and presented in bound form: The project will consist of name page, certificate, content, summary of project followed by introduction, literature survey (recently published research papers must be included), experimental techniques, results and discussion, conclusions, Appendix consisting of i) references, ii) standard spectra / data if any and iii) safety precautions.

• If student is performing project in another institute, for such a student, internal mentor must be allotted and he will be responsible for internal assessment of a student. In this case student has to obtain certificate from both external and internal mentor. Systematic record of attendance of project students must be maintained by a mentor.

• Project will be evaluated jointly by three examiners and there will not be any practical performance during the examination. Typically, student has to present his practical work and discuss results and conclusions in details (20-30 min.) which will be followed by question-answer session (10 min). It is open type of examination.

• Students are encouraged to participate in national and international conferences and other project competitions.

Course Outcome:

CO-1. understand key concepts and principles relevant to the research topic.

CO-2. learn diverse research methodologies proficiently.
CO-3. write and communicate research findings persuasively through various mediums in the form of project report CO-4. analyze and synthesize scholarly literature effectively.
CO-5. evaluate research findings and methodologies critically. 6. design and execute original research projects independently.

Savitribai Phule Pune University

Pune, India

Faculty of Science and Technology

<u>Fourth year B.Sc. Blended Honors Program</u>

Subject: **ENVIRONMENTAL SCIENCES**

Structure and Syllabus of Fourth Year

B.Sc. Blended Honors Program in Environmental Sciences

(B.Sc. Honors) Degree Program

Effective from Academic year 2026 – 2027

Structure of the Syllabus with Credit Framework

Fourth Year

Sem	Course Type	Course Code: Course Name	Credit	Sub Total
VII	**Major Core**	**EVS 401 MJ:** Habitat and Wildlife: Conservation and Management **EVS 402 MJ:** EIA and Environmental Audit **EVS 403 MJ:** Fundamentals of Environmental Biology and Biodiversity **EVS 407 MJ (P):** RP/ FP/ Industrial Traning/ Practicals	04 04 04 02	**14**
	Minor elective	**EVS 404 MN:** Atmosphere and Climnate change **EVS 405 MN:** Atmosphere and Climate Change	02 02	**04**
		Select either from the elective course basket or from Swayam / MOOC Resources: ***With prior approval of the Departmental Committee / BoS***		
	Research Method	**EVS 405 RM:** Theory of Research, Research Tools and Methods	04	**04**
		Total		22
VIII	**Major Core**	**EVS 451 MJ**: Sustainable Development Goals **EVS 452 MJ**: Disaster Management **EVS 453 MJ**: Environmental pollution and its effects on human health **EVS 457 MJ (P)**: RP/ FP/ Industrial Traning/ Practicals	04 04 04 02	**14**
	Minor elective	**EVS 454 MN:** Landscape Analyses and Remote sensing **EVS 455 MN**: Natural Resource Management	02 02	**04**
		Select any ONE course from the elective course basket or from Swayam / MOOC Resources		
		With prior approval of the Departmental Committee / BoS		
	Res. Project/ Fieldwork	**EVS 432 RP**: Dissertation		**04**
		Total		22

SEMESTER VII

EVS 401 MJ: Habitat and Wildlife: Conservation and Management (4 Credits, 60 L)

UNIT I: Fundamentals of Habitat Ecology and Wildlife Biology

Teaching Hours: 15

Topics

1. Introduction to habitat ecology
    - Concept of habitat and ecological niche
    - Types of habitats: terrestrial, aquatic, and marine
    - Habitat structure and ecosystem components
2. Wildlife biology and biodiversity
    - Classification and distribution of wildlife
    - Species diversity and endemism
    - Keystone, flagship, and indicator species
3. Ecological interactions
    - Food chains, food webs, and trophic levels
    - Predation, competition, mutualism, and symbiosis
    - Population dynamics and carrying capacity
4. Habitat fragmentation and degradation
    - Deforestation and land-use changes
    - Climate change and habitat loss
    - Invasive species and ecological imbalance
5. Wildlife distribution in India
    - Major biogeographic zones of India
    - Important wildlife habitats and biodiversity hotspots

Practical/Assignments

- Identification of habitats and wildlife species
- Preparation of food web and ecological interaction models
- Case studies on habitat degradation

UNIT II: Wildlife Conservation and Protected Area Management

Teaching Hours: 15

Topics

1. Principles of wildlife conservation
    - In-situ and ex-situ conservation
    - Conservation genetics and species recovery
2. Protected area management
    - National parks, wildlife sanctuaries, and biosphere reserves
    - Wildlife corridors and buffer zones
    - Habitat restoration and management planning
3. Wildlife laws and policies
    - Wildlife Protection Act of India
    - Convention on Biological Diversity (CBD)
    - International Union for Conservation of Nature (IUCN) categories
4. Human–wildlife conflict
    - Causes and impacts
    - Conflict mitigation strategies
    - Community participation in conservation
5. Wildlife census and monitoring techniques
    - Population estimation methods
    - Camera trapping and radio telemetry
    - GIS and remote sensing applications

Practical/Assignments

- Preparation of protected area maps
- Wildlife census data analysis
- Seminar on wildlife conservation initiatives

UNIT III: Habitat Management and Restoration Ecology

Teaching Hours: 15

Topics

1. Habitat management principles
    - Habitat evaluation and carrying capacity
    - Management of forests, grasslands, wetlands, and coastal ecosystems
2. Restoration ecology
    - Ecological succession and restoration techniques
    - Reforestation and afforestation programs
    - Wetland and mangrove restoration

3. Wildlife health and disease management
    - Wildlife diseases and zoonoses
    - Veterinary care and rehabilitation
4. Climate change and wildlife adaptation
    - Impacts of climate change on habitats and species
    - Adaptation and resilience strategies
5. Sustainable utilization of biological resources
    - Eco-development and sustainable conservation practices
    - Role of indigenous communities in habitat management

Practical/Assignments

- Habitat quality assessment exercises
- Restoration project planning
- Field study of local ecosystems

UNIT IV: Modern Approaches and Emerging Trends in Wildlife Management

Teaching Hours: 15

Topics

1. Advanced technologies in wildlife management
    - Remote sensing and GIS applications
    - Drone-based wildlife monitoring
    - Molecular tools and DNA barcoding
2. Conservation of endangered species
    - Species recovery programs
    - Captive breeding and reintroduction strategies
3. Ecotourism and conservation education
    - Principles of ecotourism
    - Environmental awareness and public participation
4. Wildlife forensics and environmental ethics
    - Wildlife crime and forensic investigation
    - Ethical issues in conservation biology
5. Emerging trends in conservation science
    - Landscape ecology and connectivity conservation
    - Citizen science and biodiversity databases
    - Global conservation challenges and future perspectives

Practical/Assignments

- GIS-based habitat analysis
- Case studies on endangered species conservation
- Seminar on recent advances in wildlife management

Course Objectives

The course aims to:

- Develop understanding of habitats, ecosystems, and wildlife diversity.
- Explain principles and strategies of wildlife conservation and habitat management.
- Familiarize students with threats to biodiversity and conservation challenges.
- Introduce modern tools and policies used in wildlife monitoring and management.

Learning Outcomes

After completion of the course, students will be able to:

1. Understand habitat ecology and wildlife diversity.
2. Explain principles and methods of wildlife conservation and management.
3. Analyze threats to biodiversity and propose mitigation measures.
4. Apply modern tools and techniques in wildlife monitoring and habitat assessment.
5. Evaluate conservation policies and sustainable management strategies.

Suggested Books and References

1. Wildlife Ecology, Conservation, and Management – Fryxell, Sinclair & Caughley
2. Fundamentals of Ecology – Eugene P. Odum
3. Principles of Conservation Biology – Martha J. Groom
4. Wildlife Management and Conservation – Paul R. Krausman
5. Biodiversity and Conservation – Peter H. Raven
6. Remote Sensing and GIS Applications in Wildlife Habitat Analysis – R.K. Sharma
7. Conservation Biology – Michael E. Soulé

EVS 402 MJ: Environmental Impact Assessment (EIA) and Environmental Audit (4 Credits, 60 L)

UNIT I: Fundamentals of Environmental Impact Assessment

Teaching Hours: 15

Topics

1. Introduction to Environmental Impact Assessment (EIA)
    - Definition, scope, and objectives of EIA
    - History and evolution of EIA
    - Environmental management and sustainable development
2. Environmental components and impacts
    - Physical, biological, and socio-economic environments
    - Types of environmental impacts
    - Impact identification and prediction
3. EIA process and methodology
    - Screening and scoping
    - Baseline environmental studies
    - Impact assessment matrices and checklists
4. Environmental legislation and policies
    - Environmental Protection Act
    - EIA Notification in India
    - National and international environmental policies
5. Public participation and environmental ethics
    - Public hearing and stakeholder participation
    - Environmental ethics and social responsibility

Practical/Assignments

- Preparation of baseline environmental data sheets
- Environmental impact identification exercises
- Case studies on major development projects

UNIT II: Techniques and Tools in Environmental Impact Assessment

Teaching Hours: 15

Topics

1. Methods of impact assessment
    - Ad hoc methods
    - Matrix and network methods
    - Overlay and GIS-based methods
2. Environmental monitoring and data analysis
    - Air, water, soil, and noise quality monitoring
    - Sampling and analytical techniques

    - Environmental quality standards
3. Risk assessment and disaster management
    - Environmental risk analysis
    - Hazard identification and mitigation
    - Disaster management planning in EIA
4. Remote sensing and GIS applications
    - Land-use and land-cover analysis
    - GIS-based environmental mapping
    - Environmental modelling techniques
5. Preparation of Environmental Management Plan (EMP)
    - Mitigation measures
    - Monitoring plans
    - Sustainable project management

Practical/Assignments

- Environmental monitoring data interpretation
- GIS-based environmental mapping exercises
- Preparation of a model EMP

UNIT III: Environmental Audit and Management Systems

Teaching Hours: 15

Topics

1. Introduction to environmental audit
    - Objectives, principles, and scope
    - Types of environmental audits
2. Environmental management systems (EMS)
    - ISO 14000 series
    - Environmental performance indicators
    - Corporate environmental responsibility
3. Audit procedures and documentation
    - Audit planning and implementation
    - Environmental statement and reporting
    - Compliance and non-compliance analysis
4. Waste management and pollution control
    - Solid waste management

    - Hazardous waste and biomedical waste management
    - Pollution prevention and cleaner production
5. Energy and resource auditing
    - Water and energy audits
    - Resource efficiency and sustainability assessment

Practical/Assignments

- Preparation of environmental audit reports
- Waste management assessment exercises
- Industrial environmental audit case studies

UNIT IV: Applied EIA, Environmental Auditing, and Emerging Trends

Teaching Hours: 15

Topics

1. Sector-specific EIA studies
    - Mining, industrial, thermal power, and infrastructure projects
    - EIA for urban and coastal development
2. Social and health impact assessment
    - Rehabilitation and resettlement issues
    - Occupational health and environmental safety
3. Climate change and environmental sustainability
    - Carbon footprint assessment
    - Climate adaptation and mitigation strategies
4. Emerging tools and technologies
    - Artificial intelligence and environmental modelling
    - Drone and satellite-based monitoring
    - Big data in environmental management
5. Recent developments and future perspectives
    - Green auditing and sustainability reporting
    - Circular economy and sustainable industrial practices
    - Future challenges in environmental governance

Practical/Assignments

- Preparation of sector-specific EIA reports
- Carbon footprint estimation exercises

- Seminar on emerging environmental management technologies

Course Objectives

The course aims to:

- Introduce the concepts, principles, and methodologies of Environmental Impact Assessment (EIA).
- Develop understanding of environmental auditing and environmental management systems.
- Explain environmental laws, policies, and regulatory frameworks related to environmental protection.
- Familiarize students with tools and techniques used in environmental planning, monitoring, and sustainable development.

Learning Outcomes

After completion of the course, students will be able to:

1. Understand the principles and procedures of Environmental Impact Assessment.
2. Apply environmental monitoring and impact assessment techniques.
3. Explain environmental auditing and management systems.
4. Evaluate environmental impacts of development projects and propose mitigation measures.
5. Understand modern trends and technologies in environmental management and sustainability.

Suggested Books and References

1. Environmental Impact Assessment – Larry W. Canter
2. Introduction to Environmental Impact Assessment – Glasson, Therivel & Chadwick
3. Environmental Management – B.B. Nath
4. Environmental Audit – Robert B. Pojasek
5. Environmental Pollution and Control – Peirce et al.
6. Remote Sensing and GIS – Basudeb Bhatta
7. Environmental Science and Engineering – P. Anandan

EVS 403 MJ: Fundamentals of Environmental Biology and Biodiversity (4 Credits, 60 L)

UNIT I: Fundamentals of Environmental Biology and Ecosystem Ecology

Topics

1. Introduction to environmental biology
    - Scope and significance of environmental biology

- Relationship between organisms and environment
- Abiotic and biotic components of ecosystems

2. Ecosystem structure and function
   - Types of ecosystems: terrestrial and aquatic
   - Energy flow and ecological pyramids
   - Food chains and food webs
3. Population and community ecology
   - Population characteristics and dynamics
   - Ecological succession
   - Species interactions: predation, competition, mutualism, and parasitism
4. Biogeochemical cycles
   - Role of microorganisms in nutrient cycling
5. Environmental pollution and ecological impacts
   - Ecological consequences of pollution
   - Climate change and ecosystem disturbances

Practical/Assignments

- Study of ecosystem components and food webs
- Preparation of ecological pyramids and nutrient cycle charts
- Case studies on environmental pollution and ecosystem changes

UNIT II: Biodiversity, Conservation, and Sustainable Management

Topics

1. Introduction to biodiversity
   - Definition, types, and levels of biodiversity
   - Genetic, species, and ecosystem diversity
2. Biodiversity distribution and hotspots
   - Global biodiversity patterns
   - Biodiversity hotspots of India and the world
   - Endemic and endangered species
3. Threats to biodiversity
   - Habitat destruction and fragmentation
   - Invasive species and overexploitation
   - Climate change and biodiversity loss

4. Biodiversity conservation strategies
    - In-situ and ex-situ conservation
    - National parks, wildlife sanctuaries, and biosphere reserves
    - Role of legislation and international conventions
5. Sustainable utilization and biodiversity management
    - Sustainable development and resource conservation
    - Community participation in biodiversity conservation
    - Traditional ecological knowledge and biodiversity management

Practical/Assignments

- Identification of local flora and fauna
- Biodiversity assessment exercises
- Seminar on conservation of endangered species

Course Objectives

The course aims to:

- Introduce the fundamental concepts of environmental biology and biodiversity.
- Develop understanding of ecosystem structure, function, and ecological interactions.
- Explain the importance of biodiversity conservation and sustainable utilization of biological resources.
- Familiarize students with environmental challenges affecting biodiversity and ecosystem stability.

Learning Outcomes

After completion of the course, students will be able to:

1. Understand the principles of environmental biology and ecology.
2. Explain ecosystem functioning and ecological interactions.
3. Identify major threats to biodiversity and ecosystem stability.
4. Apply conservation principles for sustainable biodiversity management.
5. Appreciate the importance of biodiversity in environmental sustainability.

Suggested Books and References

1. Fundamentals of Ecology – Eugene P. Odum
2. Environmental Biology – P.D. Sharma
3. Biodiversity and Conservation – Peter H. Raven
4. Ecology and Environment – P.D. Sharma

5. Conservation Biology – Michael E. Soulé
6. Environmental Science – G. Tyler Miller
7. Principles of Environmental Science – Cunningham & Cunningham

EVS 404 MN: Atmosphere and Climate Change (2 Credits, 30 L)

UNIT I: Atmosphere, Weather, and Climate Systems

Teaching Hours: 15

Topics

1. Introduction to the atmosphere
    - Composition and structure of the atmosphere
    - Atmospheric layers and their characteristics
    - Atmospheric pressure and temperature distribution
2. Atmospheric processes and circulation
    - Solar radiation and Earth's heat balance
    - Atmospheric circulation and wind systems
    - Humidity, condensation, clouds, and precipitation
3. Weather systems and climatic phenomena
    - Cyclones, anticyclones, and thunderstorms
    - Monsoon systems and El Niño–Southern Oscillation (ENSO)
    - Weather forecasting and meteorological observations
4. Climate and climatic classification
    - Climate versus weather
    - Climatic zones of the world
    - Köppen climatic classification
5. Atmospheric pollution and environmental issues
    - Air pollutants and sources
    - Acid rain, smog, and ozone depletion
    - Atmospheric aerosols and environmental impacts

Practical/Assignments

- Interpretation of weather maps and meteorological data
- Preparation of climatic graphs and charts
- Case studies on atmospheric pollution events

UNIT II: Climate Change, Impacts, and Sustainable Solutions

Teaching Hours: 15

Topics

1. Fundamentals of climate change
    - Greenhouse effect and greenhouse gases
    - Global warming and climate variability
    - Evidence and indicators of climate change
2. Causes of climate change
    - Natural and anthropogenic factors
    - Fossil fuel combustion and land-use change
    - Industrialization and carbon emissions
3. Impacts of climate change
    - Sea-level rise and glacier melting
    - Extreme weather events and biodiversity loss
    - Impacts on agriculture, water resources, and human health
4. Climate change mitigation and adaptation
    - Renewable energy and carbon management
    - Climate-resilient agriculture and sustainable development
    - International climate agreements and policies
5. Climate monitoring and modern approaches
    - Remote sensing and GIS applications in climate studies
    - Climate modelling and forecasting
    - Role of citizen participation and environmental awareness

Practical/Assignments

- Analysis of climate data and temperature trends
- Carbon footprint estimation exercises
- Seminar on climate change mitigation strategies

Course Objectives

The course aims to:

- Introduce the structure, composition, and dynamics of the atmosphere.
- Develop understanding of weather, climate systems, and climate change processes.
- Explain the causes and impacts of global climate change and environmental disturbances.
- Familiarize students with climate monitoring, mitigation, and adaptation strategies.

Learning Outcomes

After completion of the course, students will be able to:

1. Understand atmospheric structure and weather processes.
2. Explain climate systems and climatic classification.
3. Analyze causes and impacts of climate change.
4. Apply climate monitoring and assessment techniques.
5. Evaluate mitigation and adaptation strategies for sustainable environmental management.

Suggested Books and References

1. Atmosphere, Weather and Climate – Barry & Chorley
2. Climatology – D.S. Lal
3. Global Warming and Climate Change – S.K. Dash
4. Principles of Environmental Science – Cunningham & Cunningham
5. Introduction to Climate Change – R.K. Pachauri
6. Remote Sensing and GIS – Basudeb Bhatta
7. Environmental Science – G. Tyler Miller

EVS 405 MN: Ecotoxicology and E-waste Management 2 Credits (30 L)

Unit I: Principles of Ecotoxicology and Environmental Contaminants (15 Hours)

- Introduction to ecotoxicology: definition, scope, and significance
- Sources and classification of environmental pollutants
- Chemical contaminants: heavy metals, pesticides, persistent organic pollutants (POPs), pharmaceuticals, and microplastics
- Environmental fate and transport of contaminants
- Bioavailability, bioaccumulation, biomagnification, and trophic transfer
- Toxicity assessment: acute and chronic toxicity, dose-response relationship
- Biomarkers and bioindicators of environmental pollution
- Ecological and human health effects of toxic substances
- Case studies: Minamata disease, Itai-Itai disease, arsenic and fluoride contamination

Unit II: Electronic Waste Management and Sustainable Resource Recovery (15 Hours)

- Introduction to electronic waste (e-waste): definition, sources, and global scenario
- Composition and classification of e-waste
- Hazardous constituents: lead, mercury, cadmium, chromium, brominated flame retardants, and rare earth elements
- Environmental and human health impacts of improper e-waste disposal
- Collection, segregation, dismantling, recycling, and material recovery
- Urban mining and recovery of critical metals

- Circular economy and Extended Producer Responsibility (EPR)
- E-Waste (Management) Rules, India (latest amendments) and international initiatives (e.g., Basel Convention)
- Sustainable e-waste management practices and public awareness
- Case studies on successful e-waste recycling and resource recovery

Le**arning Outcomes (CLOs)**

After completing the course, students will be able to:

- Explain the basic concepts and principles of ecotoxicology.
- Evaluate the movement and ecological impacts of environmental pollutants.
- Assess the environmental and human health risks associated with e-waste.
- Describe modern e-waste recycling, recovery, and disposal technologies.
- Interpret national and international regulations related to hazardous waste and e-waste management.

Course Objectives

Upon successful completion of this course, students will be able to:

1. Understand the principles and scope of ecotoxicology.
2. Explain the fate and ecological effects of environmental contaminants.
3. Describe the composition, sources, and impacts of electronic waste.
4. Understand technologies and policies for environmentally sound e-waste management.
5. Develop awareness of sustainable resource recovery and circular economy principles.

Suggested Reference Books

1. Newman, M. C. *Fundamentals of Ecotoxicology*.
2. Walker, C. H., Sibly, R. M., Hopkin, S. P., & Peakall, D. B. *Principles of Ecotoxicology*.
3. Manahan, S. E. *Environmental Chemistry*.
4. Pepper, I. L., Gerba, C. P., & Brusseau, M. L. *Environmental and Pollution Science*.
5. LaGrega, M. D., Buckingham, P. L., & Evans, J. C. *Hazardous Waste Management*.
6. Tchobanoglous, G., & Kreith, F. *Handbook of Solid Waste Management*.
7. Government of India. *E-Waste (Management) Rules* (latest amendments).
8. Secretariat of the *Basel Convention* publications on hazardous and electronic waste.

EVS 406 RM: Theory of research, research tools and methods (4 Credits, 60 L)

Fundamentals of Research Methodology (10 L)

Meaning, objectives, and significance of research, Types of research: basic, applied, experimental, analytical, and computational, Identification and formulation of research problems, Hypothesis formulation and testing, Research planning and research design, Interdisciplinary and multidisciplinary research approaches.

Literature Survey and Scientific Documentation (10 L)

Literature survey techniques, Use of scientific databases: Scopus, Web of Science, Google Scholar, arXiv, INSPIRE, Reference management software (Zotero, Mendeley, EndNote), presentation softwares (MS Powerpoint, MS eord, LaTex)

Scientific Communication and Research Practices (10 L)

Scientific communication and technical writing of evaluation report and thesis writing. Intellectual Property Rights (IPR), patents, copyrights, and trademarks Introduction to innovation and entrepreneurship in scientific research

Research Tools and Data Analysis (10 L)

Experimental and computational tools for research, Data acquisition and data processing techniques, Error analysis and uncertainty estimation, Graph plotting and curve fitting Statistical analysis and interpretation of data, Use of software tools (Origin, MATLAB/Python basics, Excel, gnuplot).

References

1. C. R. Kothari, Research Methodology: Methods and Techniques, New Age International, 1990
2. B. L. Garg, R. Karadia, F. Agarwal and U. K. Agarwal, An introduction to Research Methodology, RBSA Publishers, 2002
3. S. M. Coley and C. A. Scheinberg, Proposal Writing, Sage Publications, 1990.
4. Research Methodology by Best and Kahn, PHI Limited.
5. Research Methodology by R. Kumar, A Step-By-Step Guide for Beginners, Pearson Education, Delhi (2006).
6. Fundamentals of modern statistical methods by Rand R.wilcox.
7. Power Analysis for Experimental Research A Practical Guide for the Biological, Medical and social Sciences by R. Barker Bausell, Yi-Fang Li Cambridge University Press.
8. Design of Experience: Statistical Principles of Research Design and Analysis, by Robert O. Kuehl Brooks/cole.
9. Panneerselvam R., Research Methodology, Prentice Hall Of India, New Delhi,2004
10. Design & Analysis of Experiments by D. C. Montgomery, 5th Ed., Wiley India (2007).

Course outcomes:

CO1: Develop a comprehensive understanding of different research methodologies and their applications in mathematics.

CO2: Cultivate critical thinking and analytical skills necessary for identifying research problems and formulating research questions.

CO3: Provide practical experience in designing experiments, collecting and analyzing data, and interpreting research results.

CO4: Foster effective communication skills for presenting research findings orally and in written form.

CO5: Promote ethical research practices and awareness of responsible conduct in mathematical research

CO5; Develop problem solving ability.

EVS 407 FP: Fieldwork/Industrial training/ Res. Praject/ Practicals (2 Credits)

Students in this course will be required to do Fieldtrip/Internship in relevant industries/government sectors/institutes, likes university, IIT's, IISER's, CSIR-NCL etc to gain practical training. As a prerequisite for industrial training, the department may conduct necessary lectures/workshops/seminars. The course will be run as per the guidelines of the Institute /the University and Government of Maharashtra. Most of our graduates are expected to seek employment in industries, pursue teaching careers, or establish small enterprises after obtaining their B.Sc Blended honors degree. Therefore, the following options would be provided to the students to develop skilled and competent students.

a) Hands on Training on various analytical instruments- UV-Visible Spectrometer, Fourier Transform Infrared Spectrometer, Nuclear Magnetic Resonance Spectrometer, Mass Spectrometry, Gas Chromatography, HPLC, X-Ray Diffractometer, Powder X-ray Diffractometer, Thermal Analyzer (TGA-DSC), Scanning electron microscope, Transmission electron microscope, BET Surface Analyzer, Raman Spectrometer, CHN Analyzer

Note: Analytical instruments (from above list) should be selected for Traning that should complete 120 hours training**.** **OR**

b) Teacher Training Course:

1) Development of MOOCS 2) Development of Learning Management System (LMS)

OR

c) Internship in Industry or National research laboratory.

OR

d) To develop Entrepreneurship, production of the following items, including packaging

1) Dye

2) Acids, caustic soda

3) Fire Extinguisher

4) Fertilizers

5) Any other industry material

OR

e) Field trip projects that are aligned with the Subject.

A detailed report should be submitted for the evaluation of field trip work /Internship.

SEMESTER VIII

EVS 451 MJ: Sustainable Development Goals (SDGs) (4 Credits, 60 L)

UNIT I: Fundamentals of Sustainable Development and SDGs

Teaching Hours: 15

Topics

1. Introduction to sustainable development
   - Concept, principles, and evolution of sustainable development
   - Environment–economy–society relationship
   - Brundtland Report and global sustainability initiatives
2. Sustainable Development Goals (SDGs)
   - United Nations 2030 Agenda
   - Overview of the 17 SDGs and targets
   - Indicators and monitoring mechanisms
3. Environmental dimensions of sustainability
   - Natural resource conservation
   - Biodiversity and ecosystem services
   - Climate change and environmental degradation
4. Social dimensions of sustainability
   - Poverty, health, and education
   - Gender equality and social inclusion
   - Human rights and community participation
5. Economic dimensions of sustainability
   - Green economy and circular economy
   - Sustainable production and consumption
   - Corporate social responsibility (CSR)

Practical/Assignments

- Preparation of SDG indicator charts
- Case studies on sustainable development initiatives
- Group discussion on local sustainability challenges

UNIT II: Resource Management and Environmental Sustainability

Teaching Hours: 15

Topics

1. Sustainable management of natural resources
    - Water, soil, forest, and mineral resources
    - Sustainable agriculture and food security
2. Energy and sustainability
    - Conventional and renewable energy resources
    - Energy conservation and efficiency
    - Sustainable energy policies
3. Waste management and pollution control
    - Solid waste and hazardous waste management
    - Pollution prevention and cleaner production
4. Urbanization and sustainable cities
    - Smart cities and urban planning
    - Sustainable transport and green infrastructure
5. Climate change and sustainability
    - Climate adaptation and mitigation
    - Carbon footprint and carbon neutrality
    - International climate agreements

Practical/Assignments

- Resource management assessment exercises
- Carbon footprint estimation
- Urban sustainability case studies

UNIT III: Policy, Governance, and Sustainable Development Planning

Teaching Hours: 15

Topics

1. Environmental governance and policy

- National and international environmental policies
- Environmental laws and institutions

2. Sustainable development planning
   - Environmental Impact Assessment (EIA)
   - Strategic Environmental Assessment (SEA)
   - Sustainability indicators and reporting
3. Role of international organizations
   - United Nations and global environmental governance
   - Role of NGOs and civil society
4. Sustainable livelihoods and rural development
   - Community-based resource management
   - Indigenous knowledge and participatory approaches
5. Education and awareness for sustainable development
   - Environmental education and ethics
   - Sustainable lifestyle practices

Practical/Assignments

- Analysis of sustainability policies and reports
- Preparation of local sustainable development plans
- Seminar on global sustainability challenges

UNIT IV: Emerging Trends and Applications of SDGs

Teaching Hours: 15

Topics

1. Technology and sustainable development
   - GIS, remote sensing, and digital technologies
   - Artificial intelligence and smart environmental management
2. Sustainable industry and green innovation
   - Green technology and eco-design
   - Sustainable industrial practices and green auditing
3. Disaster resilience and sustainable communities
   - Disaster risk reduction and climate resilience
   - Sustainable community planning
4. Monitoring and evaluation of SDGs
   - Data collection and sustainability metrics

- SDG progress assessment and reporting

5. Future perspectives and challenges
    - Global environmental challenges
    - Sustainable development in India
    - Emerging trends in sustainability science

Practical/Assignments

- GIS-based sustainability mapping
- SDG progress evaluation exercises
- Project report on sustainable community initiatives

Course Objectives

The course aims to:

- Introduce the concept and framework of sustainable development and the Sustainable Development Goals (SDGs).
- Develop understanding of environmental, social, and economic dimensions of sustainability.
- Explain global and national strategies for achieving sustainable development.
- Familiarize students with sustainability assessment, policy frameworks, and community participation.

Learning Outcomes

After completion of the course, students will be able to:

1. Understand the concept and framework of Sustainable Development Goals.
2. Explain environmental, social, and economic dimensions of sustainability.
3. Analyze sustainability challenges and policy approaches.
4. Apply sustainability assessment tools and techniques.
5. Evaluate strategies for sustainable resource management and development planning.

Suggested Books and References

1. Sustainable Development – William M. Lafferty
2. Principles of Environmental Science – Cunningham & Cunningham
3. Sustainability and Sustainable Development – A.K. Shrivastava
4. Environmental Studies – Kaushik & Kaushik
5. Our Common Future – WCED Report
6. Environmental Governance – James Meadowcroft
7. Climate Change and Sustainable Development – Munasinghe Mohan

EVS 452 MJ: Disaster Management **(4 Credit, 60L)**

UNIT I: Introduction to Disaster Management 15 Hours)

Topics

- Concept and definition of disaster
- Hazard, vulnerability, risk, capacity, and resilience
- Types of disasters:
    - Natural disasters
        - Earthquakes
        - Floods
        - Cyclones
        - Droughts
        - Landslides
        - Tsunami
    - Anthropogenic disasters
        - Industrial accidents
        - Nuclear disasters
        - Chemical hazards
        - Fire hazards
        - Biological disasters
- Disaster management cycle
    - Prevention
    - Mitigation
    - Preparedness
    - Response
    - Recovery
    - Rehabilitation
- Disaster trends at global and national levels

Learning Outcomes

Students will:

- Understand fundamental concepts of disaster management.
- Differentiate between various types of disasters.
- Explain phases of the disaster management cycle.

UNIT II: Disaster Risk Assessment and Mitigation

(15 Hours)

Topics

- Disaster risk assessment
- Hazard zonation and vulnerability analysis
- Environmental degradation and disasters
- Climate change and disaster risks
- Structural and non-structural mitigation measures
- Early warning systems
- Remote sensing and GIS applications in disaster management
- Community participation in disaster mitigation
- Sustainable development and disaster risk reduction

Learning Outcomes

Students will:

- Assess disaster risks and vulnerabilities.
- Understand mitigation strategies and technological tools.
- Relate climate change with disaster occurrence.

UNIT III: Disaster Preparedness, Response, and Recovery

(15 Hours)

Topics

- Disaster preparedness planning
- Emergency operations and response mechanisms
- Search and rescue operations
- First aid and medical preparedness
- Relief management and logistics
- Rehabilitation and reconstruction
- Psychological impacts of disasters
- Role of media and communication during disasters
- Role of NGOs, civil society, and local communities
- Case studies of major disasters in India and the world

Learning Outcomes

Students will:

- Understand disaster response mechanisms.

- Explain rehabilitation and recovery processes.
- Analyze disaster case studies critically.

UNIT IV: Policies, Institutions, and Community-Based Disaster Management

(15 Hours)

Topics

- Disaster management policies in India
- Disaster Management Act, 2005
- National Disaster Management Authority (NDMA)
- State and District Disaster Management Authorities
- International organizations and frameworks:
    - UNDRR
    - Sendai Framework for Disaster Risk Reduction
    - Red Cross and Red Crescent Movement
- Community-based disaster management (CBDM)
- Disaster education and awareness
- School and hospital safety programs
- Gender and disaster management
- Indigenous knowledge in disaster management

Course Objectives

The course aims to:

1. Introduce students to the concepts, principles, and approaches of disaster management.
2. Develop understanding of natural and anthropogenic disasters and their impacts on society and environment.
3. Familiarize students with disaster preparedness, mitigation, response, and recovery strategies.
4. Build skills related to risk assessment, emergency planning, and community resilience.
5. Encourage practical understanding of disaster management policies and institutional frameworks.

Learning Outcomes

Students will:

- Understand disaster management policies and legal frameworks.
- Explain institutional roles in disaster management.
- Develop awareness of community-based approaches.
- Understand the nature, causes, and classification of disasters.

- Analyze disaster risks and vulnerabilities in different environmental settings.
- Apply disaster preparedness and mitigation techniques.
- Explain institutional and policy frameworks related to disaster management.
- Develop community-based disaster management and resilience strategies.

Suggested Practical/Field Activities

1. Preparation of hazard maps for local areas.
2. Mock drill and evacuation planning.
3. Survey of disaster-prone regions.
4. Community awareness campaign.
5. Visit to disaster management authority or relief center.
6. Case study report on a recent disaster event.

Suggested Readings

1. Singh, R.B. – Disaster Management.
2. Coppola, D.P. – Introduction to International Disaster Management.
3. Gupta, H.K. – Disaster Management.
4. Alexander, D. – Principles of Emergency Planning and Management.
5. NDMA Guidelines and Reports.
6. Government of India – Disaster Management Act, 2005.
7. Wisner, B. et al. – At Risk: Natural Hazards, People's Vulnerability and Disasters.

References and Online Resources

- National Disaster Management Authority (NDMA)
- United Nations Office for Disaster Risk Reduction (UNDRR)
- Ministry of Home Affairs, Government of India
- Indian Meteorological Department (IMD)
- National Institute of Disaster Management (NIDM)

EVS 453 MJ: Environmental Pollution and its effects on Human Health 4 Credits (60 L)

Unit I: Introduction to Environmental Pollution (9 Hours)

- Environment and ecosystem concepts

- Components of environment
- Definition and classification of pollution
- Primary and secondary pollutants
- Natural vs anthropogenic pollution
- Sources of pollution
- Environmental cycles and pollutant transport
- Global environmental issues:
  - Global warming
  - Ozone depletion
  - Acid rain
  - Climate change

Unit II: Air Pollution and Human Health (9 Hours)

- Composition of atmosphere
- Sources of air pollution
- Criteria air pollutants
- Particulate Matter ($PM_{2.5}$ and PM_{10})
- Greenhouse gases
- Indoor air pollution
- Air Quality Index (AQI)
- Monitoring techniques
- Health impacts:
  - Respiratory diseases
  - Cardiovascular disorders
  - Lung cancer
  - Neurological effects
- Air pollution control technologies

Unit III: Water Pollution and Human Health (9 Hours)

- Surface water and groundwater pollution
- Physical, chemical and biological pollutants
- Heavy metals (Pb, Hg, Cd, As, Cr)
- Fluoride and nitrate contamination
- Industrial and municipal wastewater
- Eutrophication
- Water quality parameters
- Drinking water standards
- Waterborne diseases
- Water purification and treatment technologies

Unit IV: Soil Pollution, Waste Management and Emerging Pollutants (9 Hours)

- Sources of soil contamination
- Agricultural pollution
- Fertilizers and pesticides
- Industrial contamination

- Heavy metals in soils
- Plastic pollution and microplastics
- Biomedical waste
- Hazardous waste
- Electronic waste (E-waste)
- Radioactive pollution
- Emerging contaminants:
  - Pharmaceuticals
  - Personal care products
  - PFAS
  - Nanomaterials
- Bioremediation and phytoremediation

Course Objectives

Upon successful completion of this course, students will be able to:

1. Understand the concepts, sources, and classification of environmental pollution.
2. Explain the transport and fate of pollutants in various environmental compartments.
3. Evaluate the effects of pollutants on ecosystems and human health.
4. Learn methods for pollution monitoring and environmental quality assessment.
5. Understand environmental laws, policies, and pollution control technologies.
6. Develop awareness regarding sustainable environmental management and public health protection.

Learning Outcomes (CLOs)

After completing the course, students will be able to:

- Explain different types and sources of environmental pollution.
- Assess the impacts of pollutants on ecosystems and human health.
- Interpret environmental quality standards and pollution monitoring data.
- Demonstrate basic laboratory and field techniques for pollution assessment.
- Recommend appropriate pollution prevention and mitigation measures.
- Apply principles of environmental sustainability in pollution management.

Suggested Reference Books

1. Cunningham, W.P. & Cunningham, M.A. *Environmental Science: A Global Concern*.
2. Manahan, S.E. *Environmental Chemistry*.
3. Miller, G.T. & Spoolman, S. *Living in the Environment*.
4. Odum, E.P. & Barrett, G.W. *Fundamentals of Ecology*.
5. Pepper, I.L., Gerba, C.P. & Brusseau, M.L. *Environmental and Pollution Science*.
6. Vallero, D.A. *Fundamentals of Air Pollution*.
7. Rajagopalan, R. *Environmental Studies: From Crisis to Cure*.
8. Reddy, M.A. *Textbook of Environmental Science and Technology*.
9. Government of India. *Environmental Protection Act (1986)* and subsequent amendments.
10. World Health Organization (WHO). *Guidelines for Drinking-water Quality*.

EVS 454 MN : Landscape Analysis and Remote Sensing (2 Credits, 30 L)

UNIT I: Fundamentals of Landscape Analysis and Geomorphology

Teaching Hours: 15

Topics

1. Introduction to landscape analysis
    - Concept and scope of landscape studies
    - Components of landscapes and geomorphic systems
2. Geomorphic processes and landform development
    - Weathering, erosion, transportation, and deposition
    - Fluvial, aeolian, glacial, coastal, and tectonic landscapes
3. Morphometric analysis
    - Drainage basin characteristics
    - Slope, relief, and watershed analysis
    - Digital Elevation Models (DEM) and terrain analysis
4. Landscape evolution and environmental changes
    - Geomorphic cycles and dynamic equilibrium
    - Human impact on landscapes
    - Land degradation and conservation
5. Applications of landscape analysis
    - Natural resource management
    - Watershed management
    - Hazard zonation and environmental planning

Practical/Assignments

- Interpretation of topographic maps
- Morphometric analysis of drainage basins
- Preparation of slope and relief maps

UNIT II: Remote Sensing and Geospatial Applications

Teaching Hours: 15

Topics

1. Fundamentals of remote sensing
    - Principles and electromagnetic spectrum
    - Types of remote sensing: passive and active
    - Resolution concepts (spatial, spectral, temporal, radiometric)

2. Platforms and sensors
    - Aerial photography and satellite remote sensing
    - Sensors used in geological and environmental studies
    - Indian remote sensing satellites and applications
3. Image interpretation and digital analysis
    - Visual image interpretation techniques
    - Digital image processing and classification
    - False color composites (FCC) and spectral signatures
4. Geographic Information System (GIS)
    - Components and functions of GIS
    - Spatial data models and map overlay analysis
    - Integration of GIS and remote sensing
5. Applications in Earth and Environmental Sciences
    - Geological mapping and mineral exploration
    - Land use/land cover studies
    - Disaster management and environmental monitoring

Practical/Assignments

- Interpretation of satellite imagery and aerial photographs
- Basic GIS mapping exercises
- Land use/land cover classification project
- Seminar on recent advances in geospatial technologies

Course Objectives

The course aims to:

- Introduce concepts of landscape analysis and geomorphic interpretation.
- Develop understanding of remote sensing principles and applications in Earth Sciences.
- Explain the use of aerial photographs, satellite imagery, and GIS techniques in landscape studies.
- Familiarize students with modern geospatial technologies for environmental and geological investigations.

Learning Outcomes

After completion of the course, students will be able to:

1. Explain geomorphic processes and landscape evolution.
2. Analyze landscapes using morphometric and geospatial techniques.
3. Understand principles and applications of remote sensing.

4. Interpret aerial photographs and satellite imagery.
5. Apply GIS and remote sensing in geological and environmental studies.

Suggested Books and References

1. Remote Sensing and Image Interpretation – Lillesand & Kiefer
2. Principles of Geographical Information Systems – Peter A. Burrough
3. Geomorphology – Savindra Singh
4. Fundamentals of Remote Sensing – George Joseph
5. Remote Sensing Geology – R.P. Gupta
6. Geomorphology and Environment – Andrew Goudie
7. GIS Fundamentals – Paul Bolstad

EVS 455 MN: Natural Resource Management (2 Credit, 30L)

UNIT I: Fundamentals of Natural Resources and Environmental Management

Teaching Hours: 15

Topics

1. Introduction to natural resources
   - Definition, classification, and distribution of resources
   - Renewable and non-renewable resources
2. Land and soil resource management
   - Soil formation and degradation
   - Soil conservation and reclamation methods
   - Sustainable land-use planning
3. Water resource management
   - Surface and groundwater resources
   - Watershed management and rainwater harvesting
   - Water conservation techniques
4. Forest and biodiversity resources
   - Forest ecosystems and conservation
   - Biodiversity and ecosystem services
   - Protected areas and wildlife conservation
5. Environmental management principles
   - Environmental impact assessment (EIA)

    - Sustainable development and resource conservation policies
    - Climate change and environmental challenges

Practical/Assignments

- Preparation of resource distribution maps
- Soil and water conservation case studies
- Environmental impact assessment exercises

UNIT II: Energy, Mineral Resources, and Sustainable Resource Utilization

Teaching Hours: 15

Topics

1. Mineral resource management
    - Classification and distribution of mineral resources
    - Mining methods and environmental impacts
    - Sustainable mining practices and reclamation
2. Energy resources and management
    - Conventional and non-conventional energy resources
    - Renewable energy: solar, wind, hydro, geothermal, and biomass
    - Energy conservation and energy security
3. Resource economics and policy
    - Resource utilization and economic development
    - National resource policies and legislation
    - Community participation in resource management
4. Modern tools in resource management
    - GIS and remote sensing applications
    - Resource mapping and monitoring
    - Geospatial techniques in environmental management
5. Sustainable resource management strategies
    - Circular economy and waste management
    - Integrated natural resource management (INRM)
    - Future challenges in resource sustainability

Practical/Assignments

- Mineral and energy resource mapping exercises
- GIS-based resource analysis
- Seminar on sustainable development and resource conservation

Course Objectives

The course aims to:

- Introduce the concepts and principles of natural resource management.
- Develop understanding of the sustainable utilization and conservation of natural resources.
- Explain environmental challenges related to resource exploitation and management.
- Familiarize students with modern approaches and policies for resource conservation and sustainable development.

Learning Outcomes

After completion of the course, students will be able to:

1. Understand the classification and importance of natural resources.
2. Explain methods of conservation and sustainable utilization of resources.
3. Analyze environmental impacts associated with resource exploitation.
4. Apply geospatial and management tools in resource planning.
5. Evaluate policies and strategies related to sustainable development and resource management.

Suggested Books and References

1. Natural Resource Conservation and Management – Daniel D. Chiras
2. Environmental Science and Engineering – P. Anandan
3. Natural Resource Management – B. Mohapatra
4. Introduction to Environmental Management – Theodore & Theodore
5. Resource and Environmental Economics – Roger Perman
6. Remote Sensing and GIS – Basudeb Bhatta
7. Sustainable Development – William M. Lafferty

EVS 432 RP: Dissertation (4 Credits)

Following guidelines should be followed for the conduction and evaluation of research project.

• Each student will perform project separately. • Project working hours should be 30 hours for each credit.

• Choose a topic that aligns with your interests and career goals, but also consider its feasibility within the available resources and time frame.

• Consult with faculty members, advisors, or mentors to identify a research area that has potential for contribution to the field of chemistry.

• Adhere to ethical principles and standards in all aspects of your research.

• Project report must be written systematically and presented in bound form: The project will consist of name page, certificate, content, summary of project followed by introduction, literature survey (recently published research papers must be included), experimental techniques, results and discussion, conclusions, Appendix consisting of i) references, ii) standard spectra / data if any and iii) safety precautions.

• If student is performing project in another institute, for such a student, internal mentor must be allotted and he will be responsible for internal assessment of a student. In this case student has to obtain certificate from both external and internal mentor. Systematic record of attendance of project students must be maintained by a mentor.

• Project will be evaluated jointly by three examiners and there will not be any practical performance during the examination. Typically, student has to present his practical work and discuss results and conclusions in details (20-30 min.) which will be followed by question-answer session (10 min). It is open type of examination.

• Students are encouraged to participate in national and international conferences and other project competitions.

Course Outcome:

CO-1. understand key concepts and principles relevant to the research topic.

CO-2. learn diverse research methodologies proficiently.

CO-3. write and communicate research findings persuasively through various mediums in the form of project report CO-4. analyze and synthesize scholarly literature effectively.

CO-5. evaluate research findings and methodologies critically. 6. design and execute original research projects independently.

Savitribai Phule Pune University

Pune, India

Faculty of Science and Technology

<u>Fourth year B.Sc. Blended Honors Program</u>

Subject: PHYSICS

Structure and Syllabus of Fourth Year

B.Sc. Blended Honors degree Program in PHYSICS

Effective from Academic year 2026 – 2027

(for the batch of 2023-27)

The syllabus has been developed through a participatory and consultative process involving extensive discussions with faculty members from the discipline of Physics, along with a careful review of existing curricula and contemporary academic requirements. In accordance with the directives of the University Grants Commission (UGC) and the framework of the National Education Policy (NEP–2020), the curriculum for the undergraduate Physics program has been designed to align with the objectives of multidisciplinary, outcome-based, and skill-oriented education.

Under the autonomous framework and in accordance with the revised guidelines issued by Savitribai Phule Pune University, the Interdisciplinary School of Science has designed the B.Sc. (Honors) Physics syllabus from the academic year 2024-2025 onwards. The curriculum has been designed for review of the Board of Studies in Physics, keeping in view the contemporary relevance, emerging trends, and applications of various branches of Physics.

The process of curriculum design was initiated through a series of academic deliberations and orientation programs conducted to familiarize faculty members with the vision, principles, and implementation framework of NEP-2020. These discussions enabled effective incorporation of the key aspects of the policy, including flexibility, interdisciplinarity, experiential learning, research orientation, and outcome-based education into the revised curriculum structure.

The learning outcome-based curriculum for the B.Sc. (Physics) program is intended to provide students with a strong conceptual foundation in Physics while simultaneously developing analytical thinking, problem-solving abilities, experimental skills, and research aptitude. The curriculum is designed to prepare students for higher education, research, industry, and other professional opportunities in the field of science and technology.

While framing the syllabus, due consideration has been given to the UGC Learning Outcomes-based Curriculum Framework (LOCF), the recommendations of NEP–2020, and the model curriculum prescribed by Savitribai Phule Pune University to ensure academic quality, relevance, and alignment with national educational objectives.

Structure of the Syllabus with Credit Framework

Fourth Year

Sem	Course Type	Course Code: Course Name	Cr	Sub Total
VII	**Major Core**	**PHY 401 MJ**: Mathematical Methods in Physics **PHY402 MJ:** Computer Programming and Numerical Methods **PHY 403 MJ:** Instrumentation Circuits & Electronics **PHY 407 MJ (P):** RP/ FP/ Industrial Training/ Practicals	04 04 04 02	**14**
	Minor Elective	**PHY 404 MN:** Basics of Density Functional Theory **PHY 405 MN:** basics of Optoelectronics	02 02	**04**
		Select any ONE course from the elective course basket- *From Swayam / MOOC/ NPTEL Resources:* *With prior approval of the Departmental Committee / BoS*		
	Research Methodology	**PHY 406 RM:** Theory of Research, Research Tools and Methods	04	**04**
		Total		**22**
VIII	**Major Core**	**PHY 451 MJ:** Advance Quantum Mechanics **PHY452 MJ:** Physics of Semiconductor Devices **PHY 453 MJ:** Quantum Materials and Topological Physics **PHY 457 MJ (P):** RP/ FP/ Industrial Traning/ Practicals	04 04 04 02	**14**
	Minor Elective	**PHY 454 MN:** X ray crystallography **PHY 455 MN:** Rietveld Analysis	02 02	**04**
		Select any ONE course from the elective course basket- *From Swayam / MOOC / NPTELResources:* *With prior approval of the Departmental Committee / BoS*		
	Research Project	**PHY 432 RP:** Dissertation		**04**
		Total		**22**

Major- Core Courses Syllabus

PHY401 MJ-Mathematical Methods in Physics

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VII
Course Category	Major Core
Course Code	PHY 401 MJ
Course Title	Mathematical Methods in Physics
Credits	04

Course Objective: Mathematical Methods in Physics forms a fundamental component for the comprehensive understanding of various branches of Physics. The course is designed to equip students with essential mathematical tools and analytical techniques required for the formulation and interpretation of physical phenomena. The primary objectives of the course are:

1. To strengthen the conceptual and logical foundation underlying the mathematical formulation of physical laws and principles.
2. To introduce advanced mathematical techniques and methods that are essential for developing core concepts in Physics.
3. To enhance analytical thinking and problem-solving abilities through rigorous mathematical applications relevant to physical systems.

Module-1	Credits: 2	20 L , 10 T
	Linear Vector Spaces and Operators • Vector spaces, linear independence, basis and dimensionality, isomorphisms • Linear transformations, inverse transformations, matrices, similarity transformations • Eigenvalues and eigenvectors • Inner product, orthogonality and completeness • Complete orthogonal sets and Gram–Schmidt orthogonalization procedure • Self-adjoint and unitary transformations • Eigenvalues and eigenvectors of Hermitian and unitary operators, diagonalization • Hilbert spaces and complete orthonormal sets of functions • Weierstrass theorem (without proof) and polynomial approximation • Fourier series and applications Differential Equations and Special Functions • Power series solutions of second-order differential equations • Special functions: Legendre, Bessel, Hermite, and Laguerre equations • Legendre polynomials and associated Legendre polynomials • Spherical harmonics • Hermite polynomials	

	• Sturm–Liouville systems and orthogonal polynomials	
Module-2	Credits: 2	20 L , 10 T
	Complex Analysis • Analytic functions and Cauchy–Riemann conditions • Rectifiable arcs and line integrals • Cauchy's theorem and Cauchy integral formula • Derivatives of analytic functions and Liouville's theorem • Taylor and Laurent series • Calculus of residues • Evaluation of definite integrals and summation of series • Elementary discussion of branch cuts Applications • Principal value integrals and dispersion relations • Fourier integrals and Fourier transforms • Parseval relations and convolution theorem • Applications of Fourier transforms • Laplace transforms and Bromwich contour • Contour integral solutions of differential equations • Introduction to Green's functions and applications to partial differential equations	

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Understand linear vector spaces and eigenvalue problems frequently encountered in Physics.
2. Develop a thorough understanding of differential equations and their applications in physical systems.
3. Apply complex analytical function theory to solve problems in Physics.

Instructional Design

1. Lecture Method
2. Tutorial Method
3. Seminars

Evaluation Strategies

1. Descriptive Written Examinations
2. Assignments

References

1. Finite Dimensional Vector Spaces — P. R. Halmos (Springer Verlag)
2. Mathematics of Classical and Quantum Physics — F. W. Byron and R. W. Fuller (Dover)
3. Mathematics for Physicists — Dennery and Krzywicki (Dover)
4. Linear Algebra — K. Hoffman and R. Kunze (Pearson)
5. Algebra — M. Artin (Pearson)

PHY402 MJ-Computer Programming and Numerical Methods

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VII
Course Category	Major Core
Course Code	PHY 402 MJ
Course Title	Computer Programming and Numerical Methods
Credits	04

Course Objectives: The course is designed to provide students with a strong foundation in numerical analysis and scientific programming, enabling them to solve computational problems encountered in Physics and related disciplines. The primary objectives of the course are:

1. To introduce students to the fundamentals of numerical analysis and the basics of FORTRAN 90/95 programming language.
2. To familiarize students with important numerical techniques, computational methods, and programming concepts used in scientific computing.
3. To develop numerical, logical, and algorithmic problem-solving skills through programming applications using FORTRAN 90/95.

<table>
<tr><td></td><td>Credits: 4</td><td>40 L ,20 T</td></tr>
<tr><td></td><td>A. Introduction to Computing Environment
• Basic Linux commands and file handling
• Text editors and gnuplot (Laboratory sessions)
• FORTRAN commands and fundamentals of computer programming

B. Programming Exercises using FORTRAN 90/95
The following representative exercises are to be performed using FORTRAN 90/95 programming language:
1. Finding the largest and smallest number from a given set of numbers
2. Arranging numbers in ascending or descending order using Bubble Sort algorithm
3. Generating and printing the first hundred prime numbers
4. Matrix addition and multiplication using subroutines
5. Transpose of a square matrix using a single array
6. Evaluation of a polynomial using Horner’s method

C. Numerical Methods
Root Finding Methods
• Bisection Method
• Newton–Raphson Method
• Secant Method and applications
Regression and Curve Fitting
• Linear fitting
• Spline fitting and applications
• Determination of standard deviation and error analysis
Interpolation Techniques
• Lagrange interpolation
• Divided difference interpolation and applications</td><td></td></tr>
</table>

	Numerical Differentiation • Forward difference method • Backward difference method • Central (mean) difference method Numerical Integration • Simpson's Rule • Gaussian Quadrature and applications Differential Equations • Numerical solution of first-order differential equations using Euler's Method • Applications of Euler's Method Simultaneous Equations • Gaussian Elimination Method and applications Note: The course is expected to include approximately 20 programming and numerical exercises. Students can have option to work with C++ or Java also; if they choose to.	

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Develop proficiency in numerical analysis techniques and write scientific programs using FORTRAN 90/95.
2. Apply important numerical and computational methods to solve scientific and engineering problems.
3. Demonstrate improved numerical reasoning, algorithmic thinking, and programming skills.
4. Acquire sufficient computational background to adapt quickly to other modern programming languages and scientific computing environments.

Instructional Design

1. Lecture Method
2. Laboratory Sessions
3. Seminars

Evaluation Strategies

1. Assessment of numerical and programming skills through practical exercises and assignments
2. Viva-Voce Examination

References

1. Programming in FORTRAN 90/95 — V. Rajaraman (Prentice-Hall of India)
2. A First Course in Computational Physics (2nd Edition) — P. L. DeVries and J. E. Hasbun (Jones & Bartlett)
3. Computer Oriented Numerical Methods — V. Rajaraman (Prentice Hall of India)
4. Numerical Methods for Scientists and Engineers — H. M. Antia (Tata McGraw Hill)
5. Numerical Methods with FORTRAN IV Case Studies — Dorn and McCracken (John Wiley & Sons)
6. Numerical Recipes in FORTRAN (2nd Edition) — W. H. Press, S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery (Cambridge University Press)

PHY403 MJ- Instrumentation: Circuits and Electronics Credits: 4 | Teaching: 60 hours

Unit 1: Electronic Devices and Analog Circuits

- Semiconductor diodes, BJTs, MOSFETs, biasing and amplifier configurations.
- Operational amplifiers: characteristics, feedback, active filters, oscillators, comparators.

Unit 2: Digital Electronics and Data Acquisition

- Logic gates, combinational and sequential circuits, counters, timers.
- ADC, DAC, multiplexing, sampling theorem, data acquisition systems, microcontrollers.

Unit 3: Sensors, Transducers and Instrumentation

- Temperature, pressure, displacement, optical and magnetic sensors.
- Signal conditioning, bridges, instrumentation amplifiers, noise reduction, shielding, grounding.

Unit 4: Measurement Systems and Applications

- Oscilloscopes, spectrum analyzers, lock-in amplifiers, digital multimeters.
- Biomedical, industrial and scientific instrumentation; IoT-based measurement systems.

Suggested Laboratory/Activities

- Design and test op-amp circuits.
- Sensor interfacing using Arduino/DAQ.
- Measurement using oscilloscopes and function generators.
- ADC/DAC experiments and signal conditioning.
- Mini-project on electronic instrumentation.

PHY451 MJ- Advance Quantum Mechanics

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VIII
Course Category	Major Core
Course Code	PHY 451 MJ
Course Title	Advance Quantum Mechanics
Credits	04

Course Objectives: The primary objective of this course is to provide students with an advanced understanding of approximation methods in Quantum Mechanics and their applications to atomic systems and scattering phenomena. The course aims to strengthen the theoretical foundation required for higher studies and research in modern quantum physics. The specific objectives are:

1. To introduce the formal theory of angular momentum and identical particle systems in Quantum Mechanics.
2. To develop an understanding of time-independent and time-dependent perturbation techniques and their applications in atomic physics.
3. To familiarize students with scattering theory and approximation methods used in quantum mechanical interactions.
4. To prepare students for advanced studies in Quantum Mechanics, Atomic Physics, Condensed Matter Physics, and Quantum Field Theory.

Course Contents

Module-1	Credits: 1	20 L , 10T
	Angular Momentum and Approximation Methods • Addition of angular momenta • Clebsch–Gordan coefficients • Wigner–Eckart theorem (statement only) Identical Particles and Spin Statistics • Spin and statistics • Symmetric and antisymmetric wave functions • Slater determinants and permanents Time-Independent Perturbation Theory • Approximation methods in Quantum Mechanics • Non-degenerate perturbation theory • Degenerate perturbation theory	
Module-2	Credits: 2	20 L , 10 T
	Applications of Perturbation Theory • Fine structure of the hydrogen atom • Stark effect • Zeeman effect • Variational method and applications to the helium atom Time-Dependent Perturbation Theory • Interaction picture • Dyson series • Transition probabilities • Constant perturbation • Fermi's Golden Rule • Harmonic perturbation and transition probabilities	

	• Absorption and emission processes Interaction of Radiation with Matter • Absorption and induced emission • Electric dipole transitions • Selection rules • Decay processes and lifetime • Transition probability for spontaneous emission Approximation Methods • Adiabatic approximation • Sudden approximation Scattering Theory • Narrative overview	

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Understand the formal theory of angular momentum and identical particle systems in Quantum Mechanics.
2. Apply time-independent and time-dependent perturbation methods to quantum mechanical systems.
3. Analyze atomic spectra and interaction of radiation with matter using approximation techniques.
4. Understand and apply quantum mechanical scattering theory and partial wave analysis.
5. Develop the theoretical background necessary for advanced studies in Quantum Mechanics and Quantum Field Theory.

Instructional Design

1. Lecture Method
2. Tutorial Method
3. Seminars

Evaluation Strategies

1. Descriptive Written Examinations
2. Assignments and Problem-Solving Exercises
3. Seminar Presentations

References

1. Quantum Mechanics, Vols. I & II — Cohen-Tannoudji, Diu, and Laloe (John Wiley)
2. Modern Quantum Mechanics — J. J. Sakurai (Addison Wesley)
3. Introduction to Quantum Mechanics — D. J. Griffiths (Pearson Education)
4. Quantum Mechanics — L. I. Schiff (McGraw-Hill)
5. Principles of Quantum Mechanics — R. Shankar (Springer)
6. Quantum Physics — S. Gasiorowicz (Wiley International)
7. Quantum Mechanics: Non-Relativistic Theory — L. D. Landau and E. M. Lifshitz (Elsevier)

PHY452 MJ- Physics of Semiconductor Devices

Particulars Details
Year and Semester B.Sc. Blended Fourth Year, Semester-
VIII Course Category Major Core
Course Code PHY 452 MJ
Course Title Physics of Semiconductor
Devices Credits 04

Course Objectives: The course is designed to provide a comprehensive understanding of the physical principles governing semiconductor materials and devices. It aims to strengthen the conceptual foundation required for the analysis, characterization, design, and fabrication of semiconductor devices used in modern electronics and optoelectronics. The primary objectives of the course are:

1. To strengthen the fundamental concepts of semiconductors, carrier transport mechanisms, and p–n junction physics.
2. To introduce important concepts and characterization techniques related to semiconductor materials, metal-semiconductor junctions, and semiconductor devices.
3. To develop analytical and problem-solving skills essential for understanding, designing, and fabricating semiconductor devices and integrated electronic systems.

.

Module-1	Credits: 1	10 L , 5 T
	Carrier Transport in Semiconductors • Valence band model of pure and doped semiconductors • Equilibrium concentration of electrons and holes within the energy band gap • Fermi level and carrier energy distribution inside the bands • Temperature dependence of Fermi energy and carrier concentration in extrinsic semiconductors • Drift, diffusion, and injection of charge carriers • Carrier generation and recombination processes • Carrier lifetime and relaxation processes • Dielectric relaxation lifetime • Recombination mechanisms of electrons and holes	
Module-2	Credits: 1	10 L , 5 T

	Properties and Characterization of Semiconductors • Types of semiconductors • Direct and indirect band-gap semiconductors • Measurement of mobility and diffusivity • Optical and thermal properties of semiconductors • Four-point probe resistivity measurement • Van der Pauw method • Hall effect and Hall measurements • Haynes–Shockley experiment • Diffusion constant and carrier transport measurements • Temperature-dependent electrical properties of semiconductor	

Module-3	Credits: 1	10 L , 5 T

	Metal–Semiconductor Junctions
	
	• Formation of metal-semiconductor junctions
	• Schottky barriers and barrier formation
	• Rectifying and Ohmic contacts
	• Ideal junction conditions
	• Depletion layer formation
	• Surface and interface states
	• Role of interface states in junction diodes
	• Barrier height adjustment techniques
	• Current transport mechanisms
	• Tunneling current and minority carrier injection
	• MIS tunnel diode
	• Measurement of barrier height:
	  ○ Photoelectric measurements
	  ○ Activation energy measurements
	  ○ Capacitance–voltage measurements
	• Applications of metal-semiconductor junctions	

Module-4	Credits: 1	10 L , 5 T
	Metal–Insulator–Semiconductor (MIS) Structures • Metal–Insulator–Semiconductor capacitance • Ideal MIS capacitor • Surface space-charge region • Ideal MIS capacitance curves • Interface traps and their measurements • Oxide charges and work function difference • Carrier transport mechanisms • Non-equilibrium and avalanche phenomena • Accumulation and inversion layer thickness • Classical and quantum mechanical models • Dielectric breakdown mechanisms	

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Understand the fundamental concepts of semiconductor physics, carrier transport, and p–n junction behavior.
2. Analyze semiconductor material properties and apply characterization techniques for semiconductor devices.
3. Explain the operation and characteristics of metal-semiconductor and MIS structures.
4. Develop analytical and problem-solving skills required for semiconductor device design and fabrication.
5. Acquire the theoretical background necessary for advanced studies and research in semiconductor physics and electronic device technology.

Instructional Design

1. Lecture Method
   - Blackboard teaching
   - Concept animations and multimedia presentations
   - Video demonstrations related to semiconductor device physics
2. Tutorial Method
   - Small-group problem-solving sessions
   - Numerical exercises and conceptual discussions
3. Seminars
   - Student presentations on advanced topics related to semiconductor devices and characterization techniques

Evaluation Strategies

1. Descriptive Written Examinations
2. Assignments and Numerical Problem Solving
3. Seminar Presentations
4. Internal Assessment and Viva-Voce

References

1. An Introduction to Semiconductor Devices — Donald A. Neamen (McGraw-Hill)
2. Solid State Electronic Devices — B. G. Streetman and S. K. Banerjee (Pearson Education, 6th Edition)
3. Semiconductor Devices: Physics and Technology — S. M. Sze (John Wiley, 2nd Edition)
4. Introduction to Semiconductor Materials and Devices — M. S. Tyagi (John Wiley & Sons)
5. Fundamentals of Semiconductor Devices — B. L. Anderson and R. L. Anderson (McGraw-Hill Higher Education)
6. Principles of Semiconductor Devices — Sima Dimitrijev (Oxford University Press)
7. Complete Guide to Semiconductor Devices — K. K. Ng (John Wiley & Sons, 2nd Edition)
8. Modern Semiconductor Device Physics — S. M. Sze (John Wiley, 1998)
9. Semiconductor Devices: Basic Principles — Jasprit Singh (John Wiley & Sons)
10. Semiconductor Device Fundamentals — Robert F. Pierret (Addison-Wesley)
11. Physics of Semiconductor Devices — Dilip K. Roy (Universities Pres

PHY 453 MJ : Quantum Materials and Topological Physics **Credits: 4 | 60 hours**

Unit 1: Quantum Materials

- Electronic band theory, strongly correlated systems, quantum confinement.

- 2D materials, graphene, transition metal dichalcogenides, superconductors, multiferroics.

Unit 2: Topological Phases of Matter

- Berry phase and Berry curvature.
- Topological insulators, semimetals, edge states, bulk-boundary correspondence.

Unit 3: Spintronics and Quantum Devices

- Spin transport, spin Hall effect, Rashba interaction.
- Quantum computing materials, qubits, Majorana modes (introductory).

Unit 4: Characterization and Emerging Applications

- ARPES, STM, neutron and synchrotron techniques.
- Applications in quantum technologies, neuromorphic devices and low-power electronics.

Suggested Laboratory/Activities

- Simulation of band structures.
- Hall-effect and magnetoresistance data analysis.
- Topological insulator literature review.
- DFT software demonstration.
- Seminar on quantum materials applications.

Research Methods- Syllabus

PHY 406 RM: Theory of Research, Research Tools and Methods

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VII
Course Category	Research Methods
Course Code	PHY 405 MJ
Course Title	Theory of Research, Research Tools and Methods
Credits	04

Course Objectives: The course is designed to provide students with a comprehensive understanding of scientific research methodology, research tools, and data analysis techniques essential for academic and industrial research. The primary objectives of the course are:

1. To develop skills in literature survey, research design, scientific documentation, and technical communication.
2. To familiarize students with experimental, computational, and analytical tools used in Physics research.
3. To enhance critical thinking, data interpretation, and problem-solving abilities required for independent research work.

Module-1	Credits: 1	10 L , 5 T

	Fundamentals of Research Methodology • Meaning, objectives, and significance of research • Types of research: basic, applied, experimental, analytical, and computational • Identification and formulation of research problems • Hypothesis formulation and testing • Research planning and research design • Interdisciplinary and multidisciplinary research approaches	
Module-2	Credits: 1	10 L , 5 T
	Module II: Literature Survey and Scientific Documentation • Literature survey techniques • Use of scientific databases: Scopus, • Web of Science, Google Scholar, arXiv, INSPIRE • Reference management software (Zotero, Mendeley, EndNote) • Scientific report writing and thesis preparation • presentation software(MS-word, MS-power point LaTeX	
Module-3	Credits: 1	10 L , 5 T

	Module III: Scientific Communication and Research Practices • Scientific communication and technical writing • Evaluation report and thesis writing • Intellectual Property Rights (IPR), patents, copyrights, and trademarks • Introduction to innovation and entrepreneurship in scientific research	
Module-4	Credits: 1	10 L , 5 T
	Module III: Research Tools and Data Analysis • Experimental and computational tools in Physics research • Data acquisition and data processing techniques • Error analysis and uncertainty estimation • Graph plotting and curve fitting • Statistical analysis and interpretation of data • Use of software tools: Origin, MATLAB/Python basics, Excel, gnuplot	

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Understand the fundamental principles and methodologies involved in scientific research.
2. Conduct literature surveys and identify research gaps using scientific databases.
3. Apply appropriate experimental, computational, and analytical tools for data analysis and interpretation.
4. Prepare scientific reports, research papers, and presentations following standard academic

practices.
5. Develop independent research aptitude and scientific communication skills.

Instructional Design

1. Lecture Method
2. Tutorials and Assignments
3. Seminars and Presentations
4. Laboratory/Computer Demonstrations

Evaluation Strategies

1. Descriptive Written Examinations
2. Assignments and Numerical Problem Solving
3. Seminar Presentations
4. Internal Assessment and Viva-Voce

References

1. Research Methodology: Methods and Techniques — C. R. Kothari
2. The Craft of Research — Wayne C. Booth et al.
3. Scientific Writing and Communication — Angelika Hofmann
4. Practical Research Methods — Catherine Dawson
5. Experimental Physics: Principles and Practice — R. A. Dunlap
6. UGC Guidelines for Research and Publication Ethics

Minor – Elective Courses Syllabus

PHY404 MN- Basics of Density Functional Theory

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VII
Course Category	Minor Core
Course Code	PHY 403 MN
Course Title	Basics of Density Functional Theory
Credits	02

Course Objectives: The course is designed to introduce students to the fundamental concepts of Density Functional Theory (DFT), which is one of the most widely used computational methods in condensed matter physics, materials science, chemistry, and nanoscience. The primary objectives of the course are:

1. To provide a basic understanding of quantum mechanical treatment of many-electron systems.
2. To introduce the theoretical foundations and approximations used in Density Functional Theory.
3. To familiarize students with computational approaches and applications of DFT in modern materials research.

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Module-1	Credits: 1	10 L , 5 T

	Fundamentals of Quantum Many-Body Systems • Review of quantum mechanics of many-electron systems • Schrödinger equation for many-particle systems • Born–Oppenheimer approximation • Hartree and Hartree–Fock approximations • Exchange and correlation effects • Limitations of wavefunction-based methods • Foundations of Density Functional Theory • Electron density as the fundamental variable • Hohenberg–Kohn theorems • Variational principle in DFT • Kohn–Sham formalism • Exchange-correlation energy and functionals	
Module-2	Credits: 1	10 L , 5 T
	Exchange-Correlation Approximations • Local Density Approximation (LDA) • Generalized Gradient Approximation (GGA) • Introduction to hybrid functionals	

	Computational Methods and Applications
	
	• Self-consistent field (SCF) method
	• Basis sets and pseudopotentials
	• Introduction to electronic band structure
	• Density of states and charge density
	• Applications of DFT in:
	    o Semiconductor materials
	    o Nanomaterials and thin films
	    o Magnetic and ferroelectric materials
	
	Introduction to DFT Software Packages
	
	• Overview of computational packages:
	    o Quantum ESPRESSO
	    o VASP
	    o WIEN2k
	    o Gaussian (introductory overview only)	

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Understand the theoretical foundations of Density Functional Theory.
2. Explain the importance of electron density in many-body quantum systems.
3. Understand basic exchange-correlation approximations used in DFT calculations.

4. Interpret simple computational outputs such as band structure and density of states.
5. Appreciate the applications of DFT in materials science, condensed matter physics, and nanotechnology.

Instructional Design

1. Lecture Method
2. Tutorial Sessions
3. Computational Demonstrations

Evaluation Strategies

1. Descriptive Written Examination
2. Assignments and Problem Solving
3. Seminar Presentation / Computational Report

References

1. *Density Functional Theory: A Practical Introduction* — David Sholl and Janice A. Steckel (Wiley)
2. *Electronic Structure: Basic Theory and Practical Methods* — Richard M. Martin (Cambridge University Press)
3. *Primer in Density Functional Theory* — C. Fiolhais, F. Nogueira, and M. Marques (Springer)
4. *Density Functional Theory of Atoms and Molecules* — Parr and Yang (Oxford University Press)
5. *Computational Materials Science* — Richard LeSar (Cambridge University Press)
6. *Introduction to Computational Materials Science* — Richard LeSar (Cambridge University Press)
7. *Quantum Theory of Materials* — Efthimios Kaxiras and John D. Joannopoulos (Cambridge University Press)

PHY405 MN- Basics of Optoelectronics

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VII
Course Category	Minor Elective
Course Code	PHY 404 MN
Course Title	Basics of Optoelectronics
Credits	02

Course Objectives: The course is designed to introduce students to the fundamental principles and applications of optoelectronic devices and systems. It aims to provide an understanding of the interaction between light and semiconductor materials and the operation of modern optoelectronic components. The primary objectives of the course are:

1. To introduce the basic concepts of optoelectronics and semiconductor optical properties.
2. To understand the working principles and characteristics of important optoelectronic devices.
3. To familiarize students with modern applications of optoelectronic systems in communication, sensing, and energy technologies.

Module-1	Credits: 1	10 L , 5 T

	Fundamentals of Optoelectronics • Introduction to optoelectronics • Optical properties of semiconductors • Direct and indirect band-gap semiconductors • Electron-hole recombination processes • Absorption and emission of light in semiconductors • Radiative and non-radiative transitions Semiconductor Light Sources • Light Emitting Diodes (LEDs) • Characteristics and efficiency of LEDs • Semiconductor laser diodes • Population inversion and stimulated emission • Optical resonators and laser action • Applications of LEDs and laser diodes	
Module-2	Credits: 1	10 L , 5 T
	Optical Detectors and Solar Cells • Photoconductors and photodiodes • PIN photodiodes and avalanche photodiodes • Solar cells and photovoltaic effect • Efficiency and performance parameters of solar cells	
	Optical Communication and Applications • Basics of optical fibre communication • Optical fibres: structure and working • Optical sensors and detectors • Optoelectronic display devices • Applications in communication, medical instrumentation, imaging, and renewable energy systems	

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Understand the basic principles of optoelectronic devices and semiconductor optics.
2. Explain the operation and characteristics of LEDs, laser diodes, photodetectors, and solar cells.
3. Understand the fundamentals of optical communication systems.
4. Appreciate the role of optoelectronics in modern communication, sensing, and energy technologies.

Instructional Design

1. Lecture Method
2. Tutorial Sessions
3. Demonstrations and Multimedia Presentations
4. Seminars and Discussions

Evaluation Strategies

1. Descriptive Written Examination
2. Assignments and Problem Solving
3. Seminar Presentation / Mini Project

References

1. *Optoelectronics and Photonics: Principles and Practices* — S. O. Kasap (Pearson)
2. *Semiconductor Optoelectronic Devices* — Pallab Bhattacharya (Prentice Hall)
3. *Optical Electronics* — Ajoy Ghatak and K. Thyagarajan (Cambridge University Press)
4. *Fiber Optic Communication Systems* — Govind P. Agrawal (Wiley)
5. *Introduction to Optoelectronics* — J. Wilson and J. F. B. Hawkes (Prentice Hall)
6. *Solid State Electronic Devices* — B. G. Streetman and S. Banerjee (Pearson)
7. *Physics of Semiconductor Devices* — S. M. Sze and Kwok K. Ng (Wiley)

PHY454 MN- X-Ray Crystallography

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VIII
Course Category	Minor Elective
Course Code	PHY 404 MN
Course Title	X ray Crystallography
Credits	02

Course Objectives: The course is designed to introduce students to the fundamental principles of crystal structure analysis using X-ray diffraction techniques. It aims to provide an understanding of crystallographic concepts and experimental methods widely used in condensed matter physics, chemistry, materials science, and nanotechnology. The primary objectives of the course are:

1. To introduce the basic concepts of crystal structure, symmetry, and X-ray diffraction.
2. To understand the principles and techniques of X-ray crystallography for structure determination.
3. To familiarize students with diffraction analysis and applications in materials characterization

Module-1	Credits: 1	10 L , 5 T

	Fundamentals of Crystallography • Crystal structure and lattice concepts • Unit cell and crystal systems • Bravais lattices • Miller indices and crystal planes • Symmetry elements and point groups • Reciprocal lattice concept X-Ray Diffraction Principles • Generation and properties of X-rays • Interaction of X-rays with matter • Bragg's Law and diffraction condition $n\lambda = 2d\sin\theta$ • Laue diffraction method • Powder diffraction method • Single crystal diffraction technique	
Module-2	Credits: 1	10 L , 5 T

	Structure Determination and Analysis • Structure factor and atomic scattering factor • Indexing of diffraction peaks • Determination of lattice parameters • Phase identification using XRD patterns • Introduction to crystallographic databases (ICDD/JCPDS) Applications of X-Ray Crystallography • Crystal structure determination • Phase analysis of materials • Nanomaterials and thin-film characterization • Residual strain and crystallite size estimation • Applications in solid-state physics, chemistry, and materials science	

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Understand the fundamentals of crystal structures and symmetry.
2. Explain the principles of X-ray diffraction and Bragg's law.
3. Analyze diffraction patterns for phase identification and structure determination.
4. Apply X-ray crystallography techniques in materials characterization and research applications.

Instructional Design

1. Lecture Method

2. Tutorial Sessions
3. Demonstrations and Multimedia Presentations
4. Seminars and Discussions

Evaluation Strategies

1. Descriptive Written Examination
2. Assignments and Numerical Problems
3. Seminar Presentation / XRD Pattern Analysis

References

1. *Elements of X-Ray Diffraction* — B. D. Cullity and S. R. Stock (Prentice Hall)
2. *X-Ray Crystallography* — M. J. Buerger (Dover Publications)
3. *Crystal Structure Analysis* — Jenny P. Glusker and Kenneth N. Trueblood (Oxford University Press)
4. *Fundamentals of Crystallography* — C. Giacovazzo (Oxford University Press)
5. *Introduction to Solid State Physics* — Charles Kittel (Wiley)
6. *X-Ray Diffraction Procedures* — H. P. Klug and L. E. Alexander (Wiley)
7. *Structure Determination by X-ray Crystallography* — Mark Ladd and Rex Palmer (Springer)

PHY455 MN- Rietveld Analysis

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VIII
Course Category	Minor Elective
Course Code	PHY 404 MN
Course Title	Rietveld Analysis
Credits	02

Course Objectives: The course is designed to introduce students to the principles and applications of Rietveld refinement techniques used in powder X-ray diffraction analysis. It aims to provide a basic understanding of structural refinement methods widely used in materials science, condensed matter physics, nanotechnology, and crystallography. The primary objectives of the course are:

1. To introduce the fundamentals of powder X-ray diffraction and profile analysis.
2. To understand the principles of Rietveld refinement and crystal structure determination.
3. To familiarize students with refinement software and applications in material characterization.

Module-1	Credits: 1	10 L , 5 T

	Fundamentals of Powder Diffraction • Basics of crystal structure and diffraction • Powder X-ray diffraction (PXRD) technique • Bragg diffraction and diffraction geometry $n\lambda = 2d\sin\theta$ • Diffraction peak broadening • Instrumental and sample broadening • Crystallite size and strain effects • Phase identification using diffraction data • Introduction to crystallographic databases (ICDD/JCPDS) Introduction to Rietveld Method • Historical development of Rietveld refinement • Principle of profile fitting • Least-squares refinement technique • Goodness-of-fit parameters	
Module-2	Credits: 1	10 L , 5 T

	Structural Refinement Techniques
	
	• Background fitting and peak shape functions
	• Lattice parameter refinement
	• Atomic position and occupancy refinement
	• Thermal parameters and preferred orientation
	• Refinement of multiphase materials
	
	Software and Applications
	
	• Introduction to refinement software:
	  ○ FullProf
	  ○ GSAS
	  ○ MAUD
	• Analysis of nanomaterials and thin films
	• Structural characterization of crystalline materials
	• Applications in condensed matter physics, materials science, and chemistry	

Learning Outcomes

Upon successful completion of the course, students will be able to:

1. Understand the principles of powder X-ray diffraction and profile analysis.
2. Explain the methodology and significance of Rietveld refinement.
3. Analyze diffraction patterns and extract structural information from crystalline materials.
4. Use basic refinement software tools for structural analysis and interpretation of XRD data.
5. Appreciate the applications of Rietveld analysis in modern materials research

Instructional Design
1. Lecture Method
2. Tutorial Sessions
3. Computational Demonstrations using Refinement Software
4. Seminars and Discussions

Evaluation Strategies
1. Descriptive Written Examination
2. Assignments and Data Analysis Exercises
3. Seminar Presentation / Refinement Report

References

1. *The Rietveld Method* — R. A. Young (Oxford University Press)
2. *Elements of X-Ray Diffraction* — B. D. Cullity and S. R. Stock (Prentice Hall)
3. *Introduction to the Characterization of Nanostructured Materials* — D. C. Cox (Springer)
4. *Fundamentals of Crystallography* — C. Giacovazzo (Oxford University Press)
5. *X-Ray Diffraction Procedures* — H. P. Klug and L. E. Alexander (Wiley)
6. *Powder Diffraction: Theory and Practice* — R. E. Dinnebier and S. J. L. Billinge (Royal Society of Chemistry)

Field Project

PHY 407 FP: Field Project/Industrial Training/ RP/ Practicals

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VII
Course Category	Field Project/Industrial Training
Course Code	PHY 407 FP
Course Title	Field Project/Industrial Training
Credits	02

Students in this course will be required to do Fieldtrip work / Internship in relevant industries/government sectors/institutes, likes university, IIT's, IISER's, CSIR-NCL etc to gain practical training. As a prerequisite for industrial training, the department may conduct necessary lectures/workshops/seminars. The course will be run as per the guidelines of the Institute /the University and Government of Maharashtra. Most of our graduates are expected to seek employment in industries, pursue teaching careers, or establish small enterprises after obtaining their B.Sc Blended honors degree. Therefore, the following options would be provided to the students to develop skilled and competent students.

a) Hands on Training on various analytical instruments- UV-Visible Spectrometer, Fourier Transform Infrared Spectrometer, Nuclear Magnetic Resonance Spectrometer, Mass Spectrometry, Gas

Chromatography, HPLC, X-Ray Diffractometer, Powder X-ray Diffractometer, Thermal Analyzer (TGA-DSC), Scanning electron microscope, Transmission electron microscope, BET Surface Analyzer, Raman Spectrometer, CHN Analyzer

Note: Analytical instruments (from above list) should be selected for Traning that should complete 120 hours training**.**

OR

b) Teacher Training Course:

1) Development of MOOCS 2) Development of Learning Management System (LMS)

OR

c) Internship in Industry or National research laboratory.

OR

e) Field trip projects that are aligned with the Subject.

A detailed report should be submitted for the evaluation of field trip work /Internship.

Learning Outcomes

Upon successful completion of the Fieldwork / Industrial Training / Internship course, students will be able to:

1. Gain practical exposure to industrial, research laboratory, academic, and field-based working environments relevant to Physics and interdisciplinary sciences.
2. Develop hands-on skills in the operation, handling, and analysis of advanced scientific and analytical instruments.
3. Understand laboratory safety procedures, experimental protocols, data acquisition, and interpretation techniques used in research and industry.
4. Apply theoretical concepts learned in coursework to real-world scientific, industrial, and technological problems.
5. Enhance problem-solving, technical communication, teamwork, and professional ethics essential for research and industry careers.

Evaluation Strategies

Component	Marks	Evaluation Authority
Attendance and Participation during Training	10	Industry/Institute Mentor
Practical Skills and Technical Performance	20	Industry/Institute Mentor
Training Logbook / Laboratory Record	10	Departmental Committee
Internship / Fieldwork Report	25	Departmental Committee
Seminar Presentation	15	Departmental Committee
Viva-Voce Examination	20	Joint Evaluation Committee

Total Marks: 50

Guidelines for Evaluation

1. Students must complete the prescribed duration of training/internship/fieldwork (minimum 120 hours wherever applicable).
2. A detailed technical report documenting objectives, methodology, observations, analysis, and outcomes must be submitted.
3. Students are required to present their work through a seminar or presentation before the departmental committee.
4. Evaluation shall be based on technical understanding, practical skills acquired, quality of report, presentation, and viva-voce performance.

Field Project

PHY 457 FP: Field Project/Industrial Training/ RP/ Practicals

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VIII
Course Category	Field Project/Industrial Training
Course Code	PHY 407 FP
Course Title	Field Project/Industrial Training
Credits	02

Students in this course will be required to do Fieldtrip work / Internship in relevant industries/government sectors/institutes, likes university, IIT's, IISER's, CSIR-NCL etc to gain practical training. As a prerequisite for industrial training, the department may conduct necessary lectures/workshops/seminars. The course will be run as per the guidelines of the Institute /the University and Government of Maharashtra. Most of our graduates are expected to seek employment in industries, pursue teaching careers, or establish small enterprises after obtaining their B.Sc Blended honors degree. Therefore, the following options would be provided to the students to develop skilled and competent students.

d) Hands on Training on various analytical instruments- UV-Visible Spectrometer, Fourier Transform Infrared Spectrometer, Nuclear Magnetic Resonance Spectrometer, Mass Spectrometry, Gas Chromatography, HPLC, X-Ray Diffractometer, Powder X-ray Diffractometer, Thermal Analyzer (TGA-DSC), Scanning electron microscope, Transmission electron microscope, BET Surface Analyzer, Raman Spectrometer, CHN Analyzer

Note: Analytical instruments (from above list) should be selected for Traning that should complete 120 hours training**.**

OR

e) Teacher Training Course:

1) Development of MOOCS 2) Development of Learning Management System (LMS)

OR

f) Internship in Industry or National research laboratory.

OR

f) Field trip projects that are aligned with the Subject.

A detailed report should be submitted for the evaluation of field trip work /Internship.

Learning Outcomes

Upon successful completion of the Fieldwork / Industrial Training / Internship course, students will be able to:

1. Gain practical exposure to industrial, research laboratory, academic, and field-based working environments relevant to Physics and interdisciplinary sciences.
2. Develop hands-on skills in the operation, handling, and analysis of advanced scientific and analytical instruments.
3. Understand laboratory safety procedures, experimental protocols, data acquisition, and interpretation techniques used in research and industry.
4. Apply theoretical concepts learned in coursework to real-world scientific, industrial, and technological problems.
5. Enhance problem-solving, technical communication, teamwork, and professional ethics essential for research and industry careers.

Evaluation Strategies

Component	Marks	Evaluation Authority
Attendance and Participation during Training	10	Industry/Institute Mentor
Practical Skills and Technical Performance	20	Industry/Institute Mentor
Training Logbook / Laboratory Record	10	Departmental Committee
Internship / Fieldwork Report	25	Departmental Committee
Seminar Presentation	15	Departmental Committee
Viva-Voce Examination	20	Joint Evaluation Committee

Total Marks: 50

Guidelines for Evaluation

5. Students must complete the prescribed duration of training/internship/fieldwork (minimum

120 hours wherever applicable).

6. A detailed technical report documenting objectives, methodology, observations, analysis, and outcomes must be submitted.
7. Students are required to present their work through a seminar or presentation before the departmental committee.
8. Evaluation shall be based on technical understanding, practical skills acquired, quality of report, presentation, and viva-voce performance.

PHY 432 RP: Dissertation

Particulars	Details
Year and Semester	B.Sc. Blended Fourth Year, Semester-VIII
Course Category	Dissertation
Course Code	PHY 405 MJ
Course Title	Dissertation
Credits	04

Following guidelines should be followed for the conduction and evaluation of research project.

1. Each student will perform project separately. • Project working hours should be 30 hours for each credit.
2. Choose a topic that aligns with your interests and career goals, but also consider its feasibility within the available resources and time frame.
3. Consult with faculty members, advisors, or mentors to identify a research area that has potential for contribution to the field of chemistry.
4. Adhere to ethical principles and standards in all aspects of your research.
5. Project report must be written systematically and presented in bound form: The project will consist of name page, certificate, content, summary of project followed by introduction, literature survey (recently published research papers must be included), experimental techniques, results and discussion, conclusions, Appendix consisting of i) references, ii) standard spectra / data if any and iii) safety precautions.
6. If student is performing project in another institute, for such a student, internal mentor must be allotted and he will be responsible for internal assessment of a student. In this case student has to obtain certificate from both external and internal mentor. Systematic record of attendance of project students must be maintained by a mentor.

7. Project will be evaluated jointly by three examiners and there will not be any practical performance during the examination. Typically, student has to present his practical work and discuss results and conclusions in details (20-30 min.) which will be followed by question-answer session (10 min). It is open type of examination.
8. Students are encouraged to participate in national and international conferences and other project competitions.

Learning Outcomes

Upon successful completion of the Dissertation course, students will be able to:

1. Develop a comprehensive understanding of key concepts, theories, and principles related to the chosen research topic.
2. Identify research problems and formulate scientifically relevant research objectives and hypotheses.
3. Acquire proficiency in experimental, computational, analytical, and theoretical research methodologies.
4. Perform literature survey and critically analyze recent scientific research publications relevant to the project work.
5. Design and execute independent research work using appropriate scientific methods and techniques.
6. Analyze, interpret, and present experimental or computational results systematically and scientifically.
7. Demonstrate scientific writing and communication skills through preparation of dissertation reports, presentations, and technical discussions.
8. Develop problem-solving ability, critical thinking, research ethics, and professional competency required for higher studies, research, industry, and entrepreneurship.
9. Present and defend research findings effectively during seminar presentations and viva-voce examinations.

Instructional Design

1. Research Supervision and Mentoring
2. Laboratory / Computational Research Work
3. Literature Review and Scientific Discussions
4. Research Seminars and Progress Presentations
5. Independent Research and Technical Report Writing

Evaluation Strategies

Component	Marks	Evaluation Authority
Literature Survey and Research Planning	10	Internal Mentor
Continuous Assessment / Research Progress	20	Internal Mentor
Experimental / Computational Work and Data Analysis	25	Internal & External Examiners
Dissertation Report Writing	20	Joint Evaluation Committee
Seminar Presentation	10	Departmental Committee
Viva-Voce Examination	15	Joint Evaluation Committee

Total Marks: 100

Guidelines for Evaluation

1. The dissertation work shall be evaluated jointly by internal and external examiners.
2. Students must maintain a regular record of research progress and attendance certified by the mentor/supervisor.
3. The dissertation report should include:
    - Title page
    - Certificate
    - Acknowledgements
    - Abstract / Summary
    - Introduction
    - Literature survey
    - Experimental / Computational methodology
    - Results and discussion
    - Conclusions
    - References
    - Appendix and safety precautions (if applicable)
4. Students shall present their research work through a seminar presentation followed by a viva-voce examination.
5. Evaluation shall be based on originality of work, scientific understanding, methodology, quality of analysis, presentation skills, and ability to answer questions effectively.
6. Participation in conferences, workshops, publications, or project competitions related to the dissertation work shall be encouraged and may be considered during internal assessment.