Savitribai Phule Pune University

Pune, India

Faculty of Science and Technology

Fourth year B.Sc. Blended Program

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

Structure and Syllabus of Third Year

B.Sc. Blended 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

B.Sc. Blended honours Program (3rd year syllabus)

Structure of the Syllabus with Credit Framework for V & VI Semester (3rd year)

Level/ Difficulty	Sem	Major Core /DSC	Major Elective/DSE	Minor	GE/OE	VSC/ SEC	AEC VEC IKS	OJT, FP/CEP/CC/ RP	Total credit / SEM	Degree/ Cum.Cr
Vertical (V)		**V-1**	**V-1**	**V-2**	**V-3**	**V-1**	**V-5**	**V-5**		
5.5	**V**	**CHE 301 MJ:** Chemical Kinetics, Thermodynamics & Quantum Chemistry **CHE 302 MJ:** Catalysis and Industrial Processes **GEO 301 MJ:** Structure, Tectonics and Geodynamics of the lithosphere **GEO 302 MJ:** Hydrogeology **EVS 301 MJ:** Environmental Chemistry **EVS 302 MJ:** Environmental Law and Policy **PHY 301 MJ:** Classical Mechanics **PHY302 MJ:** Quantum Mechanics **4 Credit (T)**	**CHE 303 MJE:** Design & Synthesis of Organic Molecules **GEO 303 MJE:** Engineering Geology **EVS 303 MJE:** Environmental Geosciences **PHY 303 MJE:** Solid State Physics **4 Credit (T)**	**CHE 304 MN:**Introduction to Analytical Chemistry **GEO304MN:** Economic Geology and Mineral Exploration **EVS 304 MN:** Water & Waste Water Management **PHY 304 MN:** Electrodynamics **4 Credit (T)** **CHE/GEO/EVS/PHY 305 MN (P)** Practical lab session **2 Credit (P)**	-	**CHE 341 VSC:** Introduction to Forensic Science & tech **GEO 341 VSC:** Introduction to Marine Geology **EVS 341 VSC:** Energy & Environment **PHY 341 VSC:** Introduction to Astrophysics **2 Credit (T)**		**CHE/GEO/ EVS/PHY 331 FP/ RP:** Fieldwork/Industrial training/ Research Project **2 Credit (P)**	**22**	**UG Degree** **132**
	VI	**CHE 351 MJ:** Solid State Chemistry and its applications **CHE 352 MJ:** Bioinorganic and Coordination Chemistry **GEO 351 MJ:** Indian Stratigraphy **GEO 352 MJ:** Stratigraphic Principals and Sedimentation **EVS 351 MJ:** Environmental Impact Assessment (Theory & Practical) **EVS 352 MJ:** Environmental Biotechnology **PHY 351 MJ:** Statistical Mechanics **PHY 352 MJ:** Subatomic Physics **4 Credit (T)** **CHE 391 MJ:** Supramolecular chemistry **GEO 391 MJ:** Environmental Geoscience and Disaster Management **EVS 391 MJ:** Disaster Management & Mitigation **PHY 391 MJ:** Renewable Energy and Energy Harvesting **2 Credit (T)**	**CHE 353 MJE:** Natural Product & Heterocyclic Chemistry **GEO 353 MJE:** Remote Sensing, GIS and Applications **EVS 353 MJE:** Remote Sensing and GIS **PHY 353 MJE:** Atomic and Molecular Spectroscopy and Lasers **4 Credit (T)**	**CHE 354 MN:** Separation Techniques and advanced analytical techniques **GEO 354 MN:** Geophysical Exploration **EVS 354 MN:** Solid Waste Management **PHY 354 MN:** Digital and Analog electronics **4 Credit (T)**	-			**CHE/GEO/EVS /PHY 332 RP/ FP:** Fieldwork/Industrial training/ Research Project **4 Credit (P)**	**22**	
Year 3	**V+VI**	**08 + 10**	**04 + 04**	**06 + 04**		**02 + 00**		**02 + 04**	**44**	

Assessment and Evaluation

a) **In-semester Assessment**: 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) **Term End Examination**: 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) = $\frac{\text{Total of (Grade Points earned x Credit hours for each course)}}{\text{(Total Credit hours)}}$

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: 331 FP/ OJT: Fieldwork/Industrial training

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: 332 RP: Dissertation

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.

B.Sc Blended 3rd year chemistry major syllabus

FIFTH SEMESTER							
Course Code	**Title of the Course**	**Credits**	**Theory**	**Practical**	**CIA**	**ESE**	**Total**
CHE 301 MJ	Chemical Kinetics, Thermodynamics & Quantum Chemistry	4	4	-	50	50	100
CHE 302 MJ	Catalysis and Industrial Processes	4	4	-	50	50	100
CHE 303 MJE	Design & Synthesis of Organic Molecules	4	4	-	50	50	100
CHE 304 MN	Introduction to Analytical Chemistry	4	4	-	50	50	100
CHE 341 VSC	Introduction to Forensic Science & Technology	2	2	-	25	25	50
CHE 305 MN (P)	Chemistry Lab (Practical)	2	-	2	25	25	50
CHE 331 OJT / FP	Field Project/ OJT/ Industrial Training	2	-	2	25	25	50
	Total	22	18	4	325	325	650

SIXTH SEMESTER							
Course Code	**Title of the Course**	**Credits**	**Theory**	**Practical**	**CIA**	**ESE**	**Total**
CHE 351 MJ	Solid State Chemistry and its applications	4	4	-	50	50	100
CHE 352 MJ	Bioinorganic and Coordination Chemistry	4	4	-	50	50	100
CHE 353 MJE	Natural Product & Heterocyclic Chemistry	4	4	-	50	50	100
CHE 354 MN	Separation Techniques and advanced analytical techniques	4	4	-	50	50	100
CHE 391 MJ	Supramolecular chemistry	2	2	-	25	25	50
CHE332 RP/ FP	Field Project/ Research Project/ Industrial Training	4	-	4	25	25	50
	Total	22	20	4	325	325	650

SEMESTER V

Course Code	CHE 301 MJ	Chemical Kinetics, Thermodynamics & Quantum Chemistry	4 Credits
Core/Elective/SBS		CORE PAPER	
Unit:1	**Chemical Kinetics**		**6 L**
Order of molecularity – rate laws –1st, 2nd order kinetics - Half-life of reactions. Kinetics of Complex system: 2nd order reactions (Unequal concentration), 3rd order reactions (equal concentration).			
Unit:2	**Photochemistry**		**6 L**
Photochemical process – The primary quantum yield – Mechanism of decay of excited singlet state – Quenching – FRET - Effect of temperature.			
Unit:3	**Thermodynamics**		**08 L**
Thermodynamics of transition – Phase Diagram – Phase Rule.			
Unit:4	**Statistical thermodynamics**		**08 L**
Macrostate - Microstate – Partition functions – Thermo dynamic quantities from partition function			
Unit:5	**Quantum chemistry**		**08 L**
Black Body radiation - Heisenberg uncertainty principle - Wave particle duality, Schrödinger equation, Operators - particle in 1D/3D- Box – Postulates of quantum mechanics/ Eigen functions, values - Application to electrons linear conjugated hydrocarbons.			
Student Work • Assignments, Tutorials • Reviews of various research papers, reports, books • Presentations			**09 L**

Reference

1	Peter Atkins& Julio de Paula,"*Atkins'Physical Chemistry*" (10th edition). Reference chapters: mainly 16 &20
2	Atkins & de Paula "*Physical Chemistry*" 7th-10th ed
3	Principles of Chemical kinetics J E House
4	Physical Chemistry, A molecular approach by Donald A Mc Quarrie, John D.Simon
5	Elements of Physical Chemistry by Atkins
6	Physical Chemistry for Chemical and Biological Sciences by Raymond Chang

7	Physical Chemistry by Atkins, International Edition
Related Online Contents [MOOC, SWAYAM, NPTEL, Websites etc.]	
1. https://chem.libretexts.org/	
2. https://byjus.com/chemistry/	
3. https://openstax.org/details/books/chemistry-2e	

Course Code	**CHE 302 MJ**	**Catalysis and Industrial processes**	**4 Credits**
Core/Elective/SBS		**CORE PAPER**	
Unit:1	**Fundamental aspects of catalysis**		**04 L**
Homogeneous and Heterogeneous catalysis. The role of catalytic processes in modern chemical manufacturing - organometallic catalysts - catalysis in organic polymer chemistry - catalysis in petroleum industry - catalysis in environmental control.			
Unit:2	**Homogeneous catalysis**		**12 L**
Steam reformation, natural gas (methane), reformation of hydrocarbons, Monsanto acetic acid synthesis, alkene polymerization, Carbonylation, hydrogenation, hydroformylation, hydrogenation vs hydroformylation, Monoelectronic transfer, Shell process, Wacker acetaldehyde synthesis, photoactivated catalysis and metal cluster catalysts, Asymmetric catalysis using chiral phosphoric acids, CPA (e.g. BINOL-phosphoric acid), e.g. asymmetric hydrogenation, epoxidation, hydroformylation.			
Unit:3	**Heterogeneous catalysis**		**08 L**
Ruhrchemie/Rhone-Poulenc Oxo process using aqueous biphasic catalysis, Zeolites, their structure and properties, natural vs synthetic zeolites, zeolytes as catalysts, mesoporous materials in heterogeneous catalysis, The flue gas depollution, Energy and CO2, Hydrogenation, Oxidation, Refining technology etc.			
Unit:4	**Applied Biocatalysts**		**06 L**
Introduction to enzymes and enzyme catalysed reactions. Classification and mechanism of reaction. Purification and characterization of enzymes. Michelis Menten kinetics, Industrial enzymes. Applications of enzymes in diagnostics, analysis, biosensors and other industrial processes and bio-transformations. Enzyme structure determination, stability and stabilisation. Enzyme immobilization and concept of enzyme engineering. Nanobiocatalysis.			
Unit:5	**Photocatalysis**		**06 L**
Porphyrins -phthalocyanines and semiconductor as photo catalysts in photolysis reactions - generation of hydrogen by photo catalysts - photocatalytic break down of water and harnessing solar energy - photocatalytic degradation of dyes - environmental applications.			
Student Work • Assignments, Tutorials • Reviews of various research papers, reports, books • Presentations			**09 L**
Recommended Books/references			

1	Weller et al.(IC),6th ed,Ch21,22&25,HousecroftandSharpe(HS),4th ed,Ch26,24.2,24.7,25
2	Cotton, F.A. and Wilkinson, G. "Advanced Inorganic Chemistry", 4th Ed. John Wiley & Sons, NewYork.
3	Huheey,J.E.,Keiter, E.A.and Keiter, R.L."Inorganic Chemistry: Principles of Structures and Reactivity",4thEd.,LowPrintEdition,PearsonEducation Ltd, Asia, Reprintin India.
4	Pecoraro,V.L."Manganese Redox Enzymes", VCH: NewYork.
5	Concise Inorganic Chemistry by J.D.Lee-5th Edition.
6	Inorganic Chemistry,-D.F.Shiver&P.W.Atkins-C.H.Long ford ELBS 2nd Edition.
7	Basic Inorganic Chemistry,-F.A. Cotton and G.Wilkinson,Wiely Eastern
8	Industrial Catalysis: A practical approach by Jens Hagen Wiley (2006)
9	Industrial Catalysis: Optimizing catalysts and processes by R. I. Wijngaarden, K. R. Westerterp, and A. Kronberg
10	Handbook of Industrial Catalysts by L. Lloyd 4. Fundamentals of Industrial Catalytic Processes by C. H. Bartholomew
11	Rothenberg, G., Catalysis: Concepts and green applications, Wiley VCH, 2008
12	Gupta, B. D, Elias, A. J., Basic Oranometallic chemistry: Concepts syntheses and applications, 2nd edition, Orient Blackswan, 2013
13	Price and Stevens, Fundamentals of enzymology, Oxford University Press 2000
14	Buchholz, Kasche and Bornscheuer, Biocatalysts and Enzyme Technology, Wiley-VCH 2012
15	Polaina and MacCabe, Industrial Enzymes: Structure, Function and Applications, Springer 2007
16	B. Viswanathan, S. Kannan, R.C. Deka, Catalysts and Surfaces: Characterization Techniques, , New Delhi, 2010.
17	M. Kaneko, I. Okura, Photocatalysis: Science and Technology, Springer, 2003.

Related Online Contents [MOOC, SWAYAM, NPTEL, Websites etc.]

1. https://chem.libretexts.org/
2. https://byjus.com/chemistry/
3. https://openstax.org/details/books/chemistry-2e

Course Code	CHE 303 MJE	Design and Synthesis of Organic Molecules	4 Credits
Core/Elective/SBS		CORE PAPER	

Unit:1	Selectivity in organic synthesis	08 L

Selectivity in organic synthesis - Chemo-selectivity, Regioselectivity, Stereo- and enantio-selectivity. Introduction of Pericyclic reaction - Electrocyclic, sigma tropic, cycloaddition, chelotropic and ene reactions, photochemical cycloaddition reactions, Diels-Alder reaction, Dipolar cycloadditions, retrocycloadditions, electrocyclic reactions.

Unit:2	C-C single/ double bond formation reactions	08 L

Mechanism of Knoevenagel, Perkin, Stobbe, Darzen, Acyloin condensations, epoxidations (Prilezhaev, Sharpless, Jacobsen), Metal catalyzed C-C bond formations (Ullmann, Buchwald-Hartwig, Heck, Suzuki, Stille reactions). Phospohorus, nitrogen and sulfur ylids, Wittig reaction, Wittig-Horner reaction, Mannich reaction, Peterson olefination, McMurry reaction, β-eliminations (Hoffman & ester pyrolysis), Cope elimination, mreduction of acetylenes.

Unit:3	Oxidation and reduction reactions	08 L

Oxidations of hydrocarbons (alkanes, alkenes and aromatic), alkenes to epoxides (peroxides/per acids based), Sharpless asymmetric epoxidation, Jacobsen epoxidation, alkenes to diols (Manganese, Osmium- based), Sharpless asymmetric dihydroxylation, alkenes to carbonyls with bond cleavage (manganese, osmium, ruthenium and lead based-ozonolysis), alkenes to alcohols/carbonyls without bond cleavage (hydroboration-oxidation, chromium based allylic oxidation), ketones to α-hydroxy ketones, α,β-unsaturated ketones, Hydride reducing agents, Birch reduction, Catalytic Hydrogenation reaction, Carbonyl reduction reaction.

Unit:4	Target oriented synthesis	06 L

Designing organic synthesis, Retrosynthetic analysis, and disconnection approach, linear and convergent synthesis. Diversity-oriented synthesis: concept of forward-synthetic analysis, appendage diversity, skeletal diversity, stereochemical diversity, complexity and diversity.

Unit:5	Asymmetric Synthesis	06 L

Use of chiral auxiliaries, chiron approach. Principles and use of enzymes in the synthesis of industrially important sugar / fatty acid esters, sugar nucleotide derivatives; enantiomeric pure compounds and bio-based platform chemicals.

Student Work

- Assignments, Tutorials
- Reviews of various research papers, reports, books
- Presentations

09 L

Recommended Books/references

1	*Organic Chemistry* by J.McMurray,7th Ed., Thomson, 2008. *Principles of Organic Synthesis* by R.Norman and J.M. Coxon, 3rd Ed., Chapman and Hall, 1993. *Organic* Chemistry by J. Clayden, N. Greeves, S.Warren and P. Wothers, 2nd Ed, Oxford Press, 2012.
2	Carey,F.A. and Sundberg, R.J.,"Advanced Organic Chemistry, Part B: Reactions and Synthesis",5th Ed., Springer.
3	Clayden, J., Greeves,N. and Warren,S.,"Organic Chemistry", Oxford University Press.
4	Smith, M.B.,"Organic Synthesis",3rdEd., Academic Press.
5	Bruckner,R.,"Organic Mechanisms: Reactions, Stereo chemistry and Synthesis", Springer.

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1. https://chem.libretexts.org/
2. https://byjus.com/chemistry/
3. https://openstax.org/details/books/chemistry-2e

Course Code	**CHE 304 MN**	**Introduction to analytical chemistry**	**4 Credits**
Core/Elective/SBS		**CORE PAPER**	

Unit:1	**Fundamentals of Analytical Methods**	**06 L**

Statistics and chemo-metrics: statistical calculations, confidence limits, tests of significance, correlation coefficient, propagation of error; sampling methods: representative samples, automation of sampling and sample treatment; experimental design; quality control and assurance, volumetric and gravimetric methods; quantitative aspects of colorimetry; theory of different types of titrations: acid-base, precipitation, redox, complexometric, nonaqueous, etc.; Introduction to analytical sensors; automated method of analysis; continuous flow methods; flow injection analysis; kinetic methods of analysis; miscellaneous methods: turbidimetry, refractometry, polarimetry, optical rotatory dispersion and circular dichroism.

Unit:2	**Electroanalytical methods**	**08 L**

Introduction, electrochemical cells, types of electrodes, classifications of electroanalytical methods. Analytical applications of two-electrode systems: conductometry and potentiometry; controlled potential techniques: constant potential (e.g., amperometry), potential step (e.g., pulse techniques), and potential sweep methods (e.g., cyclic voltammetry); electrogravimetry, electrophoresis, electrosynthesis, coulometry, flow electrolysis, thin-layer electrochemistry; electrochemical sensors; electrochemical technology.

Unit:3	**Environmental Analytical Chemistry**	**06 L**

Sampling of air, water and soil for chemical analysis; monitoring techniques of air pollutants, air quality standards, pollutants standards index (PSI), monitoring of volatile organic compounds; water pollution: water quality parameters and their determination, algal blooms and algal toxins, monitoring pesticide residues in water and soil, water treatment: municipal water treatment, waste water treatment methods.

Unit:4	**Analytical Biochemistry**	**06 L**

Body fluids

Composition of body fluids and detection of abnormal levels of certain constituents leading to diagnosis of disease. Physiological and nutritional significance of water and fat soluble vitamins and minerals. Analysis for constituents of physiological fluids, viz., urine, blood, serum. Analytical techniques for vitamins including microbiological techniques.

Immunological Methods

General processes of immune response, Antigen-antibody reactions, precipitation reactions, and radio, enzyme, and fluoro-immuno assays. Human nutrition: Biological values and estimation of enzymes, carbohydrates, essential amino acids, proteins, and lipids.

Unit:5	**Spectral Methods**	**10 L**

Infra-red spectroscopy, NMR, Mass spectroscopy, Raman spectroscopy, Isotope dilution method and activation analysis, radiometric and radio-release methods Auto, X-ray and gamma radiography, Principle, Instrumentation and

applications of: Differential Thermal Analysis, Differential Scanning Calorimetry, Thermometric titrations, Evolved gas analysis, HYPHENATED TECHNIQUES : Need for hyphenation, Interfacing devices and applications of GC - MS, GC - IR, MS-MS, HPLC - MS, ICP -MS, ICP - OES.	
Student Work • Assignments, Tutorials • Reviews of various research papers, reports, books presentations	**09 L**

Recommended Books/references

1	D.A.Skoog, D.M.West, F.J.Holler and S.R.Crouch, Fundamentals of Analytical Chemistry 9E, 9th Ed., Brooks/Cole, 2014
2	D.A.Skoog, F.J. Holler and T.A.Nieman, Principles of Instrumental Analysis, 5th Ed., Thomson,1998.
3	Analytical Chemistry, G. D. Christian, 4th Ed. John Wiley, New York (1986)
4	Fundamentals of Analytical Chemistry, D .A. Skoog and D. M. West and F. J. Holler Holt- Saunders (1992)
5	Principles of Instrumental Analysis, D. A. Skoog, F. J. Holler and J.A. Niemann, 5th Edition (1998)
6	Instrumental methods of Analysis, H. H. Willard, L. L. Merritt, Jr. J. A.Dean 6th Ed CBS (1986).
7	Instrumental methods of Analysis, H. H. Willard, L. L. Merritt Jr, J. A. Dean 7th Ed CBS (1986).
8	Introduction to instrumental analysis, R. D. Braun, Mc Graw Hill (1987).
9	General, organic and biological chemistry, H. Stephen Stoker, Cengage Learning.
10	Advance dairy chemistry, vol 3, P. F. Fox, P. L. H. McSweeney Springer.
11	Physiological fluid dynamics vol 3, Nanjanagud Venkatanarayanasastry Chandrasekhara Swamy Narosa 1992.
12	Molecular Biological and Immunological Techniques and Applications for food, edited by Bert Popping, Carmen Diaz-Amigo, Katrin Hoenicke, John Wiley & sons.
13	Analytical Chemistry, G. D. Christian, 4 th Ed. John Wiley, New York (1986).
14	Fundamentals of Analytical Chemistry, D. A. Skoog and D. M. West and F. J .Holler Holt- Saunders 6th Edition (1992).
15	Principles of Instrumental Analysis, D. A. Skoog, F. J. Holler and J.A. Niemann 5th Edition (1998).
16	Instrumental methods of Analysis, H. H. Willard, L. L. Merritt Jr, J. A. Dean and F. A. Settle Jr 7th Ed CBS (1986

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1.	https://chem.libretexts.org/
2.	https://byjus.com/chemistry/
3.	https://openstax.org/details/books/chemistry-2e

Course Code	**CHE 341 VSC**	**Introduction to Forensic Science & Technology**	**2 Credits**
Core/Elective/SBS		**ELECTIVE PAPER-2**	

Unit:1	History and development of Forensic Science	06 L
Historical aspects of forensic science, Definitions and concepts of forensic science, Need of Forensic Science, Basic Principles of Forensic Science, Scope of development of forensic science. Functions of Forensic Science, Different branches of Forensic Science. Frye case and Daubert standard. Scope and development of forensic science.		
Unit:2	**Legal aspects of crime**	**03 L**
Crime – Introduction Natures, causes and consequences of crime, Broad concepts of criminal Justice system, Procedures involved in the detection of crime, Filing of criminal charges, Indian police system – The Police Act, Human rights and criminal justice system in India. Set up of INTERPOL. Duties and qualification of forensic science.		
Unit:3	**Organizational set up of FSL in India**	**03 L**
Hierarchical set up of central forensic science laboratory, Hierarchical set up state forensic science laboratory, Government examiners of questioned documents. Chemical examiners laboratory, Finger print bureaus, National crime records bureau, Bureau of police research and development, Mobile crime laboratory, Duties of forensic scientist, code of conduct of forensic scientists. Drug enforcement administrator. Defense research and development organization.		
Unit:4	**Forensic Chemistry**	**08 L**
Petroleumand Petroleum Products: Distillation and fractionation of petroleum. Commercial uses of different petroleum fractions. Analysis of petroleum products. Analysis of traces of petroleum products in forensic exhibits. Comparison of petroleum products. Adulteration of petroleum products. **Cases Involving Arson**: Chemistry of fire. Conditions for fire. Fire scene patterns. Location of point of ignition. Recognition of type of fire. Searching the fire scene. Collection and preservation of arson evidence. Analysis of fire debris. Analysis of ignitable liquid residue. Post-flashover burning. Scientific investigation and evaluation of clue materials. Information from smoke staining. **Explosives: Classification of explosives** – low explosives and high explosives. Homemade explosives. Military explosives. Blasting agents. Synthesis and characteristics of TNT, PETN and RDX. Explosion process. Blast waves. Bomb scene management. Searching the scene of explosion. Mechanism of explosion. Post blast residue collection and analysis. Blast injuries. Detection of hidden explosives		
Unit:5	**Forensic Biology**	**04 L**
Nature and importance of biological evidence. Significance of hair evidence. Transfer, persistence and recovery of hair evidence. Structure of human hair. Comparison of hair samples. Morphology and biochemistry of human hair. Comparison of human and animal hair. Types and identification of microbial organisms of forensic significance. Identification of wood, leaves, pollens and juices as botanical evidence. Diatoms and their forensic significance.		
Student Work • Assignments, Tutorials • Reviews of various research papers, reports, books • Presentations		**06 L**

Recommended Books/references	
1	B.B.Nanda and R.K.Tiwari, Forensic Science in India: A Vision for the Twenty First Century, Select Publishers, New Delhi (2001).
2	M.K.Bhasin and S.Nath, Role of Forensic Science in the New Millennium, University of Delhi, Delhi (2002).
3	S.H.James and J.J. Nordby, Forensic Science: An Introduction to Scientific and Investigative Techniques,2nd Edition, CRC Press, Boca Raton (2005)
4	W.J.Tilstone, M.L. Hastrup and C.Hald, Fisher's Techniques of Crime Scene Investigation,CRCPress, Boca Raton(2013).

Related Online Contents [MOOC, SWAYAM, NPTEL, Websites etc.]	
1.	https://chem.libretexts.org/
2.	https://byjus.com/chemistry/
3.	https://openstax.org/details/books/chemistry-2e

Course Code	CHE 305 MN (P)	Chemistry – LAB	2 Credits
Core/Elective/SBS		Minor	

List of Experiments (Any 8)	
1.	Kinetics of Alcohol Dehydrogenase – Catalysed Oxidation of Ethanol
2.	To study the phase diagram of a binary system (Phenol +water) and the effect of impurities (e.g. NaCl). Photolysis of Ethanol
3.	To determine the energy of activation for the acid catalysed hydrolysis of methylacetate
4.	Determination of specific rotation of lactic acid/sucrose by polarimeter.
5.	Determination of Na, K in a soil sample by flame photometry.
6.	Determination of glucose from food sample by glucoseoxidase method.
7.	Use of fluorescence to do "presumptive tests" to identify blood or other body fluids
8.	To study the kinetics of saponification of ester by conductometric method
9.	Oxo-synthesis: hydroformylation of propene with $[HRh(CO)(PPh_3)_3]$
10.	Oligomerization of Ethylene (SHOP Process)
11.	L-Amino Acids by Aminoacylase Process
12.	Catalytic hydrogenations with metal catalysts based on Ni, Co, Pd, or Pt.
13.	Knoevenagel condensation between aldehyde (4-diethylaminobenzaldehyde) and malonic acid, cyano acetic acid or malononitrile.
14.	Preparation of pyridinium dichromate and its use in oxidation of benzyl alcohol

15.	Synthesisoftrans-9-(2-Phenylethenyl) anthracene
16.	Asymmetric reduction of EAA by using Baker's yeast

CHE 331 FP/ RP – Field Project/ Industrial Training/ Research Project – 2 Credits

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students will be assigned to the on campus faculty/ research scientists from various national research institutes such as NCL/ IISER/ working in chemistry research; under whose guidance he or she would work on a problem keeping the focus to enhance their own ability to critical thinking, identification of research problems and research gaps, formulate research objectives, formulation of research plan, and problem solving via execution of specific experiments, and develop specialized skills to handle specific problems. This would train the students to nurture their creativity and innovative ideas, collaboration/teamwork and leadership, communications, learning self-reliance and project management.

Adequate assessment requirements for individual marking are presentations with discussions and seminars on the working process and the results.

SEMESTER VI

Course code	CHE 351 MJ	Solid State chemistry & its Applications	4 Credits
Core/Elective/SBS		CORE PAPER	

Unit:1	Fundamentals	10 L

Types of solids - close packing of atoms and ions - bcc, fcc and hcp voids –Gold schmidt radius ratio - derivation - its influence on structures - structures of rock salt -cesium chloride - wurtzite - zinc blende - rutile - fluroite - antifluorite - diamond and graphite-spinel - normal and inverse spinels and perovskite - lattice energy of ionic crystals -Madelung constant - Born-Haber cycle and its applications. **Theories -** Band theory of solids. Free electron Theory, zone theory, MO theory of Solids dislocation in solids: Schottky and Frenkel defects. Line defects and plane defects – nonstoichiometric compounds. Electrical properties: Energy bands, insulators, semiconductors and conductors- super conductors-dielectric properties, piezo-electricity, ferro electricity- conductivity in pure metals. Superconductivity: Occurrence, BCS theory, high temperature super conductors- introduction to nanoparticles- metal nanoparticles- particle size determination.

Unit:2	X- Ray diffraction	04 L

Theory- the crystal systems and Bravais lattices - Miller indices and labeling of planes - symmetry properties - crystallographic point groups and space groups - X-ray diffraction - powder and rotating crystal methods - systematic absences and determination of lattice types - analysis of X-ray data for cubic system - structure factor and Fourier synthesis -Fundamentals of electron and neutron diffraction.

Unit:3	Chemistry of Nanostructure Materials	09 L

Introduction; fundamentals of nanomaterials science, surface science for nanomaterials, colloidal chemistry; Synthesis, preparation and fabrication: chemical routes, self-assembly methods, biomimetic and electrochemical approaches; Size controls properties (optical, electronic and magnetic properties of materials) - Applications (carbon nanotubes and nanoporous zeolites; Quantum Dots, basic ideas of nano devices).

Introduction to nanoscience and nanotechnology - Underlying physical principles of nanotechnology: Nanostructured Materials: Size is Everything. Fundamental physicochemical principles - size dependence of the properties of nanostructured matter -quantum confinement, single electron charging, the central importance of nanoscale morphology. Societal aspects of nanotechnology: Health, environment, hype and reality. The advent of the nanomaterial. Top down and bottom-up approaches to building materials. Properties of nanomaterials such as nanoparticles, carbon nanotubes. Overview of self-assembly. Inert gas condensation, arc discharge, RF plasma, plasma arc technique, ion sputtering, laser ablation, laser pyrolysis, ball milling, molecular beam epitaxy, chemical vapour deposition method and electro deposition.

Unit:4	The basic tools of nanotechnology	05 L

Scanning electron microscopy (SEM), TEM and EDAX analysis and X-ray diffraction, A brief historical overview of atomic force microscopy (AFM) and an introduction to its basic principles& applications. Optical microscope and their description, operational principle and application for analysis of nanomaterials, UV-Vis-IR spectrophotometers, Principle of operation and application for band gap measurement.

Unit:5	Metal nanoparticles &	08 L

	Carbon based Nanomaterials	

Metal nanoparticles - Size control of metal nanoparticles and their characterization, study of their properties- optical, electronic, and magnetic. Surface plasmon band and its applications, role in catalysis, alloy nano particles, stabilization in sol, glass, and other media, change of band gap, blueshift, colour change in sol, glass, and composites, Plasmon resonance

Carbon based Nanomaterials - Introduction. Fullerenes, C60, C80 and C240 nanostructures. Properties & applications (mechanical, optical and electrical). Functionalization of carbon nanotubes, reactivity of carbon nanotubes. Nano-sensors: Temperature sensors, smoke sensors, sensors for aerospace and defence. Accelerometer, pressure sensor, night vision system, nano tweezers, nano-cutting tools, integration of sensor with actuators and electronic circuitry biosensors.

Student Work	**09 L**
• Assignments, Tutorials • Reviews of various research papers, reports, books • Presentations	

Recommended Books/references

1	Nanoparticles-Theory and Applications by Schmid
2	Carbon Nanomaterials by Challa
3	Nanomaterials-Synthesis, properties and applications by Rao CNR, Miller A, Cheetham AK.
4	Solid State Chemistry and it's Applications by West
5	Nanoscale materials in Chemistry by Klabunde
6	Carbon Nanotubes – Basic Concepts and Physical Properties by Reich S, Thomsen C, Maultzsch J
7	T. Pradeep, Nano: The Essentials, Tata McGraw-Hill, New Delhi, 2007.
8	G. Cao, Nanostructures and Nanomaterials – Synthesis, Properties and Applications, Imperial College Press, London, 2004, chapters 3, 4 and 5.
9	C. N. R.Rao, A. Muller and A. K. Cheetham, The Chemistry of Nanomaterials, Volume Wiley –VCH Verlag GmbH & Co. KgaA, Weinheim, 2004, Chapter 4.

Related Online Contents [MOOC, SWAYAM, NPTEL, Websites etc.]

1. https://chem.libretexts.org/
2. https://byjus.com/chemistry/
3. https://openstax.org/details/books/chemistry-2e

Course Code	CHE 352 MJ	Bioinorganic and Coordination chemistry	4 Credits
Core/Elective/SBS		CORE PAPER	

Unit:1	Metal ligands in biological system	09 L

- Amino acid side chains, specialized ligands, porphyrins, enterobactin, etc.,
- Availability of Fe, Cu and Zn
- Uptake of Fe, gut, transferrin and ferritin
- oxygen transport
- Zn- source of nucleophilic–OH, Cu-essential but toxic
- photosynthesis-chlorophyll reaction centre and oxygen evolving centre

Unit:2	Theories of coordination compounds	09 L

VB theory - CFT - splitting of d orbitals in ligand fields and different symmetries - CFSE - factors affecting the magnitude of 10 Dq – evidence for crystal field stabilization - spectrochemical series - site selection in spinels – tetragonal distortion from octahedral symmetry - Jahn-Teller distortion - Nephelauxetic effect – MO theory - octahedral - tetrahedral and square planar complexes-bonding and molecular orbital theory - experimental evidence for -bonding.

Unit:3	Reactions	12 L

Substitution reactions in square planar complexes - the rate law for nucleophilic substitution in a square planar complex - the trans effect - theories of trans effect - mechanism of nucleophilic substitution in square planar complexes - kinetics of octahedral substitution - ligand field effects and reaction rates - mechanism of substitution in octahedral complexes - reaction rates influenced by acid and bases - racemization and isomerization - mechanisms of redox reactions - outer sphere mechanisms - excited state outer sphere electron transfer reactions - inner sphere mechanisms - mixed valent complexes.

Unit:4	Electronic spectra and magnetism	06 L

Microstates, terms and energy levels for d1 – d9 ions in cubic and square fields - selection rules - band intensities and band widths - Orgel and Tanabe-Sugano diagrams - evaluation of 10 Dq and β for octahedral complexes of cobalt and nickel - charge transfer spectra -magnetic properties of coordination compounds - change in magnetic properties of complexes in terms of spin orbit coupling - temperature independent paramagnetism - spin cross over phenomena.

Structure - Structure of coordination compounds with reference to the existence of various coordination numbers (2, 3, 4, 5 & 6) - site preferences - isomerism - trigonal prism - absolute configuration of complexes - stereo selectivity and conformation of chelate rings - coordination number seven and eight. Spectral and magnetic properties of lanthanide and actinide complexes.

Unit:5	IR, Raman and EPR spectroscopy	06 L

Structural elucidation of simple molecules like N_2O, ClF_3, NO_3^-, and ClO_4^- - effect of coordination on ligand vibrations - uses of group vibrations in the structural elucidation of metal complexes of urea, thiourea, cyanide, thiocyanate, nitrate, sulphate and DMSO - effect of isotopic substitution on the vibrational spectra of molecules - applications of Raman spectroscopy.

EPR - theory and instrumentation, spin Hamiltonian, isotropic and anisotropic EPR spectra, magic pentagon rule, applications of EPR spectroscopy (i) in structure determination of coordination complexes and (ii) metalloproteins (Fe and Cu).	
Student Work • Assignments, Tutorials • Reviews of various research papers, reports, books • Presentations	**09 L**

Recommended Books/references

1	Housecroft and Sharpe,3rd ed, Chap 29; Weller et al,6thed,Chap 26.
2	Cotton,F.A.,Wilkinson,G.,Murillo,C.A.andBochmann,M.,"AdvancedInorganicChemistry",6th Ed., John Wiley & Sons
3	Huheey,J.E., Keiter,E.A. and Keiter,R.L., "Inorganic Chemistry Principle of Structure and Reactivity",4thEd, Pearson Education, Inc.
4	Douglas,B.E.,McDaniel,D.H.andAlexander,J.J.,"ConceptsandModelsinInorganicChemistry",3rd Ed., John Wiley & Sons
5	Figgis, B.N.,andHitchman,M.A "Ligand Field Theory and Its Applications", WileyEasternLtd.
6	J. E. Huheey, E. A. Keiter and R. L. Keiter, Inorganic Chemistry, Principles of Structure and Reactivity, 4thEdition, Harper Collin College Publishers, 1993.
7	F.A. Cotton and G.Wilkinson, Advanced Inorganic Chemistry, 4th& 5thEdns, Wiley Interscience, New York, 1998.
8	R.S. Drago, Physical Methods in Inorganic Chemistry, 3rd Edition, Wiley Eastern, 1992.
9	J. Lewis, R.G. Wilkins, Modern Coordination Chemistry, Inter Science Publisher, 1960.
10	D. F. Shriver, P. W. Atkins and C. H. Langford, Inorganic Chemistry, Oxford University Press, Oxford, l994.
11	K. Nakamoto, Infrared and Raman Spectra of Inorganic and Coordination Compounds, Part A &Part B, 2ndEdn, Wiley. 2009.
12	G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edn, Pearson Prentice Hall, 2005 8. J.E. House, Inorganic Chemistry, Elsevier, 2008.
13	J.E. House, Inorganic Chemistry, Elsevier, 2008

Related Online Contents [MOOC, SWAYAM, NPTEL, Websites etc.]

1.	https://chem.libretexts.org/
2.	https://byjus.com/chemistry/
3.	https://openstax.org/details/books/chemistry-2e

Course Code	**CHE 353 MJE**	**Natural Product and Heterocyclic chemistry**	**4 Credits**
Core/Elective/SBS		**CORE PAPER**	
Unit:1	**Classification of natural products**		**05 L**

Chemical structure, classification, structure elucidation based on degradative reactions- Isolation and structural elucidation of selected alkaloids and terpenes- quinine, morphine, and reserpine, citral, juvabione and logiofolene – Insect pheromones.		
Unit:2	**Amino Acids, Peptides and Proteins**	**05 L**
Classification of Amino Acids, Zwitterion structure and Isoelectric point. Synthesis of amino acids-reactions - properties- Amino Acids in Nature: - Amino Acids and their Metabolites in Nature –Structure of proteins- Peptides.		
Unit:3	**Steroids &Carbohydrates**	**10 L**
Steroids - Classification- Synthesis and structure elucidation of cholesterol, conversion of cholesterol to progesterone- aldosterone and testosterone-cortisone- Vitamin D – Nucleic Acids- structure of nucleosides and nucleotides-RNA and DNA, Watsons and Crick model DNA-drug interaction. Carbohydrates- Classification of carbohydrates, reducing and non-reducing sugars, General properties of glucose and fructose, their open chain structure. Epimers, muta-rotation and anomers. Determination of configuration-Hudson's rules-Structure of sugars transformation of sugars, Preparation of alditols, glycosides, deoxysugars. Synthesis of vitamin C from glucose.		
Unit:4	**Heterocycles**	**08 L**
Synthesis, Properties and uses of Five membered heterocyclic ring systems with one or two hetero atoms-Furan, pyrrole, thiophene and thiazole: six membered heterocyclic ring system-Pyridine. Fused heterocyclic ring systems-Indole, quinoline. Biologically important heterocycles: Pyrimidines and purines		
Unit:5	**New materials derived from heterocycles**	**08 L**
Syntheses of cyanines and related dyes. Organic sensitizers for DSSC, electron donors and acceptors for organic solar cells, optical chemo-sensors and organic semiconductors for thin-film transistors.		
Student Work • Assignments, Tutorials • Reviews of various research papers, reports, books • Presentations		**09 L**

Recommended Books/references

1	Designing organic Synthesis by Stuart Warren1983.
2	Organic Chemistry by Cramand Hammond.
3	Organic Chemistry by Clayden, Greeves, Warren and Wothers
4	Organic Chemistry by I.L.Finar Vol.II Vth Edn.
5	Spectrometric identification of organic compounds R.M.Silverstein,
6	L. Finar, Organic Chemistry Vol. I & Vol. II- Pearson Education, 6thedn.
7	F. A. Carey and R. J. Sundberg, (Eds) 3rd Edition, Part B. Plenum/Rosetta, 1990.

8	I. Fleming, Selected Organic Synthesis, John Wiley and sons, 1982.
9	Atta-ur-Rahman, Studies in Natural Products Chemistry, Vol.1 and 2, Elsevier, 1988.
10	R. Krishnaswamy, Chemistry of Natural Products; A Unified Approach, Universities Press.
11	R. J. Simmonds: Chemistry of Biomolecules: An Introduction, RSC.
	Related Online Contents [MOOC, SWAYAM, NPTEL, Websites etc.]
1.	https://chem.libretexts.org/
2.	https://byjus.com/chemistry/
3.	https://openstax.org/details/books/chemistry-2e

Course Code	**CHE 354 MN**	**Separation Techniques and Advanced Analytical Techniques**	**4 Credits**	
Core/Elective/SBS		**CORE PAPER**		
			Syllabus Version	**2023-24**

Unit:1	**Extractions techniques**	**08 L**

- Partition law and its limitations, distribution ratio, separation factor, factors influencing extraction, multiple extractions. Extraction of metal. Technique of extraction: batch, continuous and counter current extractions. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and non- aqueous media.

Unit:2	**Chromatography**	**14 L**

- Introduction and classification, theory of column chromatography, retention time, retention volume, capacity factor, concept of plate and rate theory, resolution, column performance, normal and reverse phase chromatography, paper and thin layer chromatography, ion-exchangers.
- **GC principle, instrumentation, Application**
- Introduction, Theory, Principle, GSC and GLC, Separation mechanism involve in GSC and GLC, Instrumentation of Gas chromatography, working of gas chromatography, gas chromatogram and qualitative –quantitative analysis. Application of Gas chromatography
- **HPLC principle, instrumentation, Application**
- Introduction, Need of liquid chromatography, Separation mechanism involved in adsorption and partition HPLC, Instrumentation and working of HPLC, Applications of HPLC,
- Introduction to supercritical fluid chromatography.

Unit:3	**Mass spectrometry**	**06 L**

GCMS/LCMS

Unit:4	Data Analysis	02 L
Quantitative chemical analysis; calculation of analytical results (calibration curve method, standard addition method, internal standards method) Significant figures: confidence and interval; Student's T-test; F-test; Q-test.		
Unit:5	**Sensor**	**04 L**
Introduction, Classifications of sensors, Sensitivity and Limit of detection, Types of Sensors- Optical, Electrochemical & Biosensor. Application of Sensor in environmental and biological samples.		
Student Work • Assignments, Tutorials • Reviews of various research papers, reports, books • Presentations		**09 L**

Recommended Books/references

1	Textbook of Quantitative Chemical Analysis - 3rd Edition, A.I.Vogel
2	Principles of Physical Chemistry 4th edition–Prutton and Marron
3	Instrumental Methods of Chemical Analysis- Chatwal and Anand
4	Basic Concept of Analytical Chemistry-2nd edition S.M. Khopkar
5	Vogel's textbook of Quantitative Inorganic Analysis-4th edition Besset Denney, Jaffrey, Mendham
6	Instrumental Methods of Chemical Analysis- 6th edition Willard, Merritt, Dean and Settle
7	Analytical Chemistry by Skoog
8	Introduction to Instrumental Analysis- R.D. Braun Instrumental methods of Chemical Analysis-Willard, Dean &Merrit- 6th Edition
9	Instrumental methods of Chemical Analysis-Willard, Dean & Merrit- 6th Edition.

Related Online Contents [MOOC, SWAYAM, NPTEL, Websites etc.]

1. https://chem.libretexts.org/
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3. https://openstax.org/details/books/chemistry-2e

Course Code	CHE 391 MJ	Supramolecular chemistry	2 Credits
Core/Elective/SBS		ELECTIVE PAPER-4	

Unit:1	Fundamentals of supramolecular chemistry	01 L
Introduction-the meaning of supramolecular chemistry, phenomenon of molecular recognition and their quantification.		
Unit:2		**08 L**
Building blocks of supramolecular chemistry- acyclic receptors for neutral and charged guests, macrocycles and crown ethers, macrobicycles and cryptands, macro polycycles, cucurbiturils and cyclodextrins.		
Unit:3		**06 L**
Sensors and information processing, electro-optic phenomena, molecular machines		
Unit:4		**02 L**
Amphiphilic molecules and their aggregation, Langmuir-Blodgettry, molecular recognition at the air-water interface.		
Unit:5		**07 L**
Discrete and polymeric metal-organic hybrid materials- guest inclusion, catalysis and other applications. Future scopes.		
Student Work • Assignments, Tutorials • Reviews of various research papers, reports, books • Presentations		**06 L**

Recommended Books/references

1	Steed, J.W. and Aswood, J.L., "Supramolecular Chemistry", Wiley.
2	Dodziuk, H, "Introduction to Supramolecular Chemistry", Springer, ISBN 1402002149.
3	Beer, P.D., Gale, P.A. and Smith, D.K., "Supramolecular Chemistry", Oxford Chemistry Printers, ISBN-10: 0-19-850447-0.
4	Cragg, P., "A Practical Guide to Supramolecular Chemistry", Wiley-VCH, ISBN: 0-470-86654-3.
5	Schneider, H.J. and Yatsimirsky, A.,"Principles and Methods in Supramolecular Chemistry", Wiley-VCH, ISBN: 0-471-97253-3.
6	Supramolecular Chemistry: Concepts and Perspectives, J.-M. Lehn, VCH, Weinheim, 1995.
7	Principles and Methods in Supramolecular Chemistry, H. J. Schneider and A. Yatsimirsky, Wiley, New York, 2000.
8	Supramolecular Chemistry, J. W. Steed and J. L. Atwood, John Wiley & Sons, Chichester, 2009.

CHE 332 FP/ RP/ OJT **4 Credits**

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students will be assigned to the on campus faculty/ research scientists from various national research institutes such as NCL/ IISER/ working in chemistry research; under whose guidance he or she would work on a problem keeping the focus to enhance their own ability to critical thinking, identification of research problems and research gaps, formulate research objectives, formulation of research plan, and problem solving via execution of specific experiments, and develop specialized skills to handle specific problems. This would train the students to nurture their creativity and innovative ideas, collaboration/teamwork and leadership, communications, learning self-reliance and project management.

Adequate assessment requirements for individual marking are presentations with discussions and seminars on the working process and the results.

Summer training / Internship -

Even though summer training/internship is not mandatory and not a part of curriculum; students will be encouraged to work as summer trainee or interns in other institutes/ laboratories/ industries depending upon the scopes and availability during summer/winter recess.

After the period of training, it is expected that students achieve the following:

- Recognize the duties, responsibilities and ethics at a professional position.
- Ability to apply knowledge learned to solve specific problems in relevant domain of science.
- Gain exposure and practical experience in the relevant field.
- Ability to prepare technical reports for the training.
- Ability to communicate effectively in the work environment.

Proposed Curriculum Structure for the B. Sc. (Blended) Earth Science Course

(Semesters V – VI)

Nomenclature: GEO – Earth Science

Semester V		
Subject Code	Title of the Subject	Credits
GEO 301 MJ	Structure, Tectonics and Geodynamics of the lithosphere	4
GEO 302 MJ	Hydrogeology	4
GEO 303 MJE	Engineering Geology	4
GEO 304 MN	Economic Geology and Mineral Exploration	4
GEO 341 VSC	Introduction to Marine Geology	2
GEO 305 MN (P)	Geology Lab	2
GEO 331 RP/ FP/ OJT	Project/Dissertation/ Field Project/ Industrial training	2
Total Credits		22

Semester VI		
Subject Code	Title of the Subject	Credits
GEO 351 MJ	Indian Stratigraphy	4
GEO 352 MJ	Stratigraphic Principals and Sedimentation	4
GEO 353 MJE	Remote Sensing, GIS and Applications	4
GEO 354 MN	Geophysical Exploration	4
GEO 391 MJ	Elective 3 - Environmental Geoscience and Disaster Management	2
GEO 332 RP/ FP/OJT	Project/Dissertation	4
Total Credits		22

Semester V

GEO 301 MJ - Structure, Tectonics and Geodynamics of the lithosphere	
Topic Details	**Lectures**
Concept of isostacy, ocean floor spreading, continental drift, plate tectonics. Definition of plate, platform and shield. Different tectonic settings on Earth (MOR, Rift valleys, Island arcs).	36
Concept of strike and dip, Dipping strata, unconformities, Brunton compass, Understanding stress and strain, ductile vs. brittle deformation, the effects of temperature, time, pressure, pore fluids and strain rate on rock strength, and the mechanisms of rock deformation.	
Definition, elements, types and nature of joints, fractures, shear zones, faults, and folds.	

Recommended Books/references:

- *Patwardhan, A.M. (2012) The dynamic Earth System, PHI Learning Pvt. Ltd.,*
- *Moores E.M. and Twiss R.J. (1995) Tectonics, W. H. Freeman*
- *Valdiya, K.S.,(1984) Aspects of Tectonics: Focus on Southcentral Asia, Tata-McGraw Hill, New Delhi,*
- *Beloussov, V.V. (1980) Geotectonics, Springer-Verlag Berlin Heidelberg*
- *Condie, K.C.(1989) Plate Tectonics &Crustal Evolution, Butterworth-Heinemann*
- *Billings, M.P. (1942) Structural Geology, Prentice Hall,*
- *Badgley, P. C. (1965) Structural & Tectonic Principles, Harper & Row*
- *Valdiya K.S. (2014) Making of India, Springer.*
- *Valdiya K.S. (1984) Aspects of tectonics, Tata Mcgrath Hill.*

GEO 302 MJ- Hydrogeology	
Topic Details	**Lectures**
Qualitatively and quantitatively investigations of the fundamental physical and chemical processes governing groundwater flow and composition.	36
Aquifer properties: porosity, permeability, regional geology and hydrology.	
Hydrogeology of crystalline rocks, water-rock interactions, and subsurface microbial activity.	
Well inventory, Field and laboratory methods used to characterize aquifer properties and including well pumping tests.	
Groundwater chemistry: major ion and isotope analyses and chemical tracers.	
Groundwater Resources of India with special reference to each state. Groundwater quality hotspots in India: TDS, F, Ar, U, Fe, etc.	

Recommended Books/references:

- *Todd, D.K. and Mays, L.W. (2004) Groundwater Hydrology, John Wiley & Sons.*
  2. Karanth, K.R. (1987) Groundwater Assessment Development and Management,Tata McGraw-Hill Education.
- *Raghunath, H.M. (1987) Groundwater,New Age International*
- *Davis, S.N. and Dewiest R.J.M. (1966) Hydrogeology, John Wiley & Sons.*
- *Freeze, R. A. and Cherry, J. A. (1979) Groundwater, Prentice Hall*
- *Hiscock, K. M. (2005) Hydrogeology: Principles and Practice, Blackwell Publishing*
- *Kresic, N. (1997) Hydrogeology and Groundwater Modeling, Lewis Publishers Brassington, R. (2017) Field Hydrogeology, Wiley Blackwell*
- *Hudak, P. F. (1999) Principles of Hydrogeology, Lewis Publishers*
- *Pawar, N.J, Das, S. And Duraiswami R.A (2012) Hydrogeology of Deccan Traps and associated Formations in Peninsular India, Geol. Soc. India, Bangalore.*
- *Das Subhajyoti (2011) Groundwater Resources of India. National Book Trust. 1st Edition, 248 p.*

GEO 303 MJE – Engineering Geology	
Topic Details	**Lectures**
Topics include: engineering properties of soil and rock geological site investigations of slopes, foundations tunnels, dams, mines, roads, and other developments. Building stones and aggregates. Geophysical survey methods used in Engineering Geology (e.g. Electrical Resistivity).	36

Recommended Books/references:

- *Blyth, F.G.H. and M. H. de Freitas (1984) Geology for Engineers,ButterworthHeinemann*
- *Krynine, D.P and Judd, W.R (2005) Principles of Engineering Geology and Geotechniques, CBS Publishers & Distributors*
- *Ries, H. and T. L. Watson, (1949) Elements of Engineering Geology, New York, John Wiley & Sons, Inc.*
- *Tony Waltham (2009) Foundations of Engineering Geology, Taylor and Francis.*
- *Chenna Keshvallu (2018) Text book of Engineering Geology, Laxmi Publications.*
- *Gokhale, K.V.G. (2006) Principles of engineering geology, BS publications.*

GEO 304 MN - Economic Geology and Mineral Exploration	
Topic Details	**Lectures**
Indian occurrences of metallic (iron, manganese, chromite, copper, lead zinc, gold, etc.) and non-metallic (barite, fire clay, gypsum, bauxite, etc.) deposits.	36
Type of mineral deposit, ore forming processes, mineral exploration techniques.	
Coal and petroleum geology. Construction and building material, dimension stones. Uranium-Thorium and REE minerals, Environmental and social issues that relate to mineral resource extraction will also be discussed.	

Recommended Books/references:

- *Tiwari S.K. (2010) Ore Geology, Economic Minerals and Mineral Economics, Atlantic Publishers & Distributors (P) Limited*
- *Aswathanarayana, U.(2005) Mineral Resources Management and the Environment, Nalkema Publishers*
- *Guilbert, John M. and Charles Frederick Park(2007) The Geology of Ore Deposits, Waveland Press*
- *Arogyaswamy R.N.P. (2017) Courses in mining geology, Oxford and IBH publishers*

GEO 341 VSC - Introduction to Marine Geology	
Topic Details	**Lectures**
Physical oceanography, ocean salinity and ocean currents. El-Nino-La Nino effect relation between climate and ocean in the Indian context.	24
Exclusive economic zones and their economic potential. Principles behind echo sounder and side scan sonar systems and seismic methods.	
Physiographic divisions of oceans, Origin, stricter and evolution of Indian Ocean shelf and margins (estuaries, deltas, tidal flats).	
Approach to be interdisciplinary requiring integration of biological, chemical, physical and geological processes. Past historical impact of sea level changes, coastal erosion and conservation methods, Coastal Regulatory Zones	

Recommended Books/references:

- *Kenneth, J. (1982) Marine Geology and Geophysics.*
- *Wright J. and Colling A. (1995) Seawater: its Composition, Properties and Behaviour, The Open University*
- *The Open University (1989) Ocean chemistry and deep sea sediments.*
- *Dronkers J. (2005) Dynamics of coastal systems, World Scientific*
- *Woodroffe, C.D. (2013) Coast: Form, process and evolution, Cambridge University Press.*
- *Nittrouer, C.A., Austin, J. A., Field M. E., Kravitz J. H., SyvitskiJ. P. M., Wiberg P.L.(2007) Continental margin, sedimentation from sediment transport to sequence stratigraphy, Wiley Blackwell.*
- *Bender, M. (2013) Paleoclimate, Princeton Premiers in Climate*
- *Bradley R. S., (1999), Paleoclimatology: Reconstructing climates of the quaternary. Academic Press v. 64 of International Geophysical series.*
- *Einsele, G. (1982) Sedimentary basins-evolution, facies and sediment budget. Springer-Verlag.*
- *Ruddiman, W.F. (2008) Earth's Climate, Past and Future, WH Freeman & Co.*

CHE 331 FP/ RP/ OJT **2 Credits**

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students will be assigned to the on campus faculty/ research scientists from various national research institutes such as NCL/ IISER/ working in chemistry research; under whose guidance he or she would work on a problem keeping the focus to enhance their own ability to critical thinking, identification of research problems and research gaps, formulate research objectives, formulation of research plan, and problem solving via execution of specific experiments, and develop specialized skills to handle specific problems. This would train the students to nurture their creativity and innovative ideas, collaboration/teamwork and leadership, communications, learning self-reliance and project management.

Adequate assessment requirements for individual marking are presentations with discussions and seminars on the working process and the results.

Summer training / Internship -

Even though summer training/internship is not mandatory and not a part of curriculum; students will be encouraged to work as summer trainee or interns in other institutes/ laboratories/ industries depending upon the scopes and availability during summer/winter recess.

After the period of training, it is expected that students achieve the following:

- Recognize the duties, responsibilities and ethics at a professional position.
- Ability to apply knowledge learned to solve specific problems in relevant domain of science.
- Gain exposure and practical experience in the relevant field.
- Ability to prepare technical reports for the training.
- Ability to communicate effectively in the work environment.

Semester VI

GEO 351 MJ – Indian Stratigraphy	
Topic Details	**Lectures**
Precambrian evolution of Peninsular India. Stratigraphy and evolution of Dharwar Craton, Aravalli craton, Singhbhum craton, etc. Central Indian Suture Zone	36
Introduction to Proterozoic basins of India Gondwana, sedimentation Mesozoic basins of India Deccan Traps volcanic province	
Introduction to Himalayas: Physiographic divisions and tectono-magmatic evolution.	

Recommended Books/references:

- *Wadia, D. (1973) Geology of India. McGraw Hill Book co*
- *Krishnan, M.S. (1982) Geology of India and Burma, 6th Edition. CBS Publ.*
- *Ramakrishnan M, and Vaidynadhan, R (1994) Geology of India, Geological Society of India Publication, Bangalore. Vol. I & II.*
- *Valdiya K.S.(2010) The Making of India: Geodynamic Evolution, Springer*
- *Valdiya K.S. (1984) Aspects of tectonics, Tata Mcgrath Hill.*
- *Ravindrakumar (2018) Fundamentals of Historical Geology and Stratigraphy of India, Newage Publications*

GEO 352 MJ – Stratigraphic Principals and Sedimentation	
Topic Details	**Lectures**
An introduction to the principles of stratigraphy	36
Nature of sediment formation, transport and deposition Concept of Sedimentary Facies	
Use of primary and secondary sedimentary structures in the interpretation and reconstruction of sedimentary facies, Paleogeography, past climates, and depositional histories.	

Recommended Books/references:

- *Friedman & Sanders, (1978) Principles of Sedimentology. John Wiley and sons. Pettijohn, F.J., (1975. Sedimentary rocks, Harper & Bros. 3rd Ed.*
- *Sengupta. S., (1997) Introduction to sedimentology. Oxford-IBH.*
- *Pettijohn F.J. (1984) Sedimentary Rocks (3rd Edition), CBS Publishers and Distributors, New Delhi.*

GEO 353 MJE - Remote Sensing, GIS and Applications	
Topic Details	**Lectures**
Basic concepts in remote sensing, electro-magnetic spectrum. Energy sources, energy interaction in the atmosphere, atmospheric windows, atmospheric effects on remotely sensed data.	36
Aerial photo interpretation, photo-recognition elements, methods of photointerpretation, advantages and limitations of aerial photographs.	
Signatures in remote sensing, sensors and sensor platforms Introduction to aerial photographs, history of aerial photography, aerial camera, types of aerial photographs, classification, principles of stereoscopic viewing, conditions and cause for stereovision.	
Visual image interpretation of satellite imagery, image enhancement, digital analysis, preparation of thematic maps.	
Thermal Infrared remote sensing and microwave remote sensing for geological applications.	
Remote sensing satellites, Indian Remote Sensing Satellite programme.	

Recommended Books/references:

- *Miller Victor C. Miller Calvin F. (1961) Photogeology (International Series in the Earth Sciences. McGraw-Hill Book Company, Inc.*
- *Drury S.A, A Guide to Remote Sensing - Interpreting Images of Earth, Oxford Science Publications, Oxford. (1990)*
- *Sabins, F.F.Jr., (1978) Remote Sensing Principles and Interpretation, Freeman, Sanfrancisco.*
- *Paine, D.P (1981) Aerial photography and image interpretation for resource management, Wiley and Sons, New York. 1986.*
- *Gary L.Prost Remote Sensing for Geologists - A Guide to Image interpretation, Gordon and Breach Science Publishers, The Netherlands. 1997.*
- *Reddy A. (2012) Introduction to Remote Sensing and GIS, BS Publications.*
- *Ramasamy, SM. (1999) Trends in Geological Remote Sensing - Rawat Publishers,Jaipur Rao, D.P. Remote Sensing for Earth Resources, Second Edition, Association of Exploration Geophysicist, Hyderabad p.212, (CERS-236)*

GEO 354 MN – Geophysical Exploration	
Topic Details	**Lectures**
Principles and limitations of geophysical exploration, petrophysical properties of rocks, survey methods.	36
Introduction to gravity and magnetic surveying, processing and interpretation steps involved for gravity and magnetic methods	
Elements of seismic surveying, concept of seismic refraction and reflection, ray paths in layered media and interpretation.	
Electrical Resistivity method - Equipment, Vertical electrical sounding vs. Electrical profiling, Slumberger vs. Wenner configuration, Interpretation of resistivity data. Application of geophysical exploration.	

Recommended Books/references:

- *Dobrin, M B and Savit C H. (1988) Introduction to Geophysical Prospecting, McGraw Hill Inc.*
- *Ramachandra Rao and Prasaranga, M B. (1975) Outlines of Geophysical Prospecting - A Manual for Geologists by University of Mysore, Mysore.*
- *Bhimasarikaram V.L.S., (1990) Exploration Geophysics - An Outline by Association of Exploration Geophysicists, Osmania University, Hyderabad.*
- *Telford, W. M., Geldart, L. P., and Sheriff, R. E., (1990) Applied geophysics (vol. 1). Cambridge University Press.*
- *Lowrie, W., (2007) Fundamentals of Geophysics. Cambridge University Press.*
- *Parasnis D. S. (1986): Well Logging in Oil Fields, In: Principles of Applied Geophysics, Springer.*

GEO 391 MJ – Environmental Geoscience and Disaster Management	
Topic Details	**Lectures**
Surface and subsurface water resources, hydrogeologic cycle and pollution, point, line and area sources of pollution. Water quality parameters, BIS standards, organic and inorganic pollutants, heavy metal pollution, remedial measures. Earthquakes and their prediction, Richter scale, seismic hazard zoning map of India, Building codes and public education. Different types of volcanoes, volcanic hazards and their occurrence in the plate tectonic context. Cyclones and Floods, fundamental river processes and the interaction between a river and its floodplain. Examine the costs and benefits, to both humans and to ecosystems, of both technological approaches (e.g., dams and levees) and land-use planning approaches (floodplain mapping and zoning) to avoiding flood damages. Droughts, meteorological, agricultural and hydrologic types, mitigation of droughts. Landslides, different types and evaluation of technologies for preventing landslides.	24

Recommended Books/references:

- *Valdiya, K. S., (1987) Environmental Geology - Indian Context. Tata McGraw Hill New Delhi.*
- *Keller, E. A., (2000) Environmental Geology. Shales E. Merril Publishing Co., Columbus, Ohio.*
- *Montgomery, C., (1984) Environmental Geology. John Wiley and Sons, London.*
- *Bird, Eric, (2000) Coastal Geomorphology: An Introduction. John Wiley & Sons, Ltd. Singapore.*
- *Liu, B.C., (1981) Earthquake Risk and Damage, Westview.*
- *Sharma J. P., Environmental Studies, Laxmi Publications (P) Ltd, New Delhi*

CHE 332 FP/ RP/ OJT **4 Credits**

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students will be assigned to the on campus faculty/ research scientists from various national research institutes such as NCL/ IISER/ working in chemistry research; under whose guidance he or she would work on a problem keeping the focus to enhance their own ability to critical thinking, identification of research problems and research gaps, formulate research objectives, formulation of research plan, and problem solving via execution of specific experiments, and develop specialized skills to handle specific problems. This would train the students to nurture their creativity and innovative ideas, collaboration/teamwork and leadership, communications, learning self-reliance and project management.

Adequate assessment requirements for individual marking are presentations with discussions and seminars on the working process and the results.

Summer training / Internship -

Even though summer training/internship is not mandatory and not a part of curriculum; students will be encouraged to work as summer trainee or interns in other institutes/ laboratories/ industries depending upon the scopes and availability during summer/winter recess.

After the period of training, it is expected that students achieve the following:

- Recognize the duties, responsibilities and ethics at a professional position.
- Ability to apply knowledge learned to solve specific problems in relevant domain of science.
- Gain exposure and practical experience in the relevant field.
- Ability to prepare technical reports for the training.
- Ability to communicate effectively in the work environment.

Proposed 3rd year Syllabus (Academic year 2026 - 2027)

T Y B. Sc. (Blended) – Environmental Science Stream

SEM V		
Subject Code	**Title of the Subject**	**Credits**
EVS 301 MJ	Environmental Chemistry	4
EVS 302 MJ	Environmental Law and Policy	4
EVS 303 ME	Environmental Geosciences	4
EVS 304 MN	Water & Waste Water Management	4
EVS 341 VSC	Energy & Environment	2
EVS 305 MN (P)	Environmental Science - LAB	2
EVS 331 RP	Project/ Dissertation/ Field Project/ OJT	2
Total Credits		**22**

SEM VI		
Subject Code	**Title of the Subject**	**Credits**
EVS 351 MJ	Environmental Impact Assessment (Theory & Practical)	4
EVS 352 MJ	Environmental Biotechnology	4
EVS 353 MJE	Remote Sensing and GIS	4
EVS 354 MN	Solid Waste Management	4
EVS 391 MJ	Disaster Management & Mitigation	2
EVS 332 RP	Project/ Dissertation/ Field Project/ OJT	4
Total Credits		**22**

Syllabus Details

SEMESTER V

EVS 301 MJ - Environmental Chemistry	
Topic Details	**No. of Lectures**
Introduction to Green Chemistry What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.	4
• Principles of Green Chemistry and Designing a Chemical synthesis • Twelve principles of Green Chemistry with their explanations and examples; • Designing a Green Synthesis using these principles; • Prevention of Waste/ byproducts; • Maximum incorporation of the materials used in the process into the final products (Atom Economy); • Prevention/ minimization of hazardous/ toxic products; • Designing safer chemicals – different basic approaches to do so; • selection of appropriate auxiliary substances (solvents, separation agents), green solvents, solvent-less processes, immobilized solvents and ionic liquids; • energy requirements for reactions - use of microwaves, ultrasonic energy; • selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups; • use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; • designing of biodegradable products; prevention of chemical accidents; • strengthening/development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes	12
Water Chemistry - Reversible and irreversible reactions of water, Cations and anions in water and their sources, Mass Balancing, concepts of DO, BOD, COD, sedimentation, coagulation, filtration, redox potential.	4
Soil Chemistry - Chemistry of salt-affected soils and amendments; soil pH, EC, ESP, SAR; Soil Pollution Management;	4

Future Trends in Green Chemistry Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solvent-less reactions; non-covalent derivatization; Green chemistry, in sustainable development.	6
Student work - Assignments, Tutorials - Reviews of various research papers, reports, books - Presentations	15

Suggested Reading:

1. Manahan S. E, Environmental Chemistry, CRC Press 2010
2. Girard J., Principles of Environmental Chemistry, Jones Bartlett Learning, 2014
3. A. K. Dey. Environmental Chemistry- New Age International publishers.
4. Bela Torok and Timothy Dransfield (ed.). Green Chemistry. 2017. Elsevier
5. V. K. Ahluwalia. 2013. Green Chemistry: A Textbook. Alpha Science International.
6. Harrison R., Principles of Environmental Chemistry, RSC 2007
7. Hanrahan G., Key concepts of Environmental Chemistry, Elsevier Inc. 2012

EVS 302 MJ - Environmental Law & Policy	
Topic Details	**Lectures**
Introduction to law and Policy • Sources of law, Concepts, Definitions • Difference between policy and law • Historical background	4
International & Indian environmental movements • Principles of international environmental law • Difference between Indian and Western environmentalism • Modern Environmental movements (Chipko, Apiko, Narmada bachao etc.) • Role of civil society in environmental movements • Indian Government's response to International Conventions / Regulations	3
International Environmental Organizations • Various organisations and institutions (e.g. UNEP, UNFCC, IPCC, etc.) • Changing role of NGOs/ Institutions in conservation and protection of environment • Nexus between natural resources and tribal/ethnic communities • Natural resources and competing human rights.	4

Role of constitution in environment protection • Fundamental rights and duties, Article 48A, 51A (g), 58A, Any relevant Amendments, etc. **Environmental Legislation Indian Context**: • Water Act, 1974 • Air Act, 1981 • Indian Forest Act, 1927/1982 • Environment Protection Act, 1986 • The National Green Tribunal Act 2010 • National Environment Policy • Forest Policy	6
Introduction to major international conferences/ conventions: • The Stockholm Declaration of 1972; • United Nations Conference on Environment and Development 1992; • Rio de Janeiro (Rio Declaration, Agenda 21); • Montreal Protocol 1987; • Kyoto Protocol 1997; • Ramsar convention: • Cartagena Protocol • Convention on Biological Diversity	5
Overview of institutional framework in India • Agencies of Governance and their role in green governance • Government ministries, departments defining policies and laws (MoEFCC, Pollution Control Boards, Forest Department, National Biodiversity Authority, etc.) • Important autonomous boards, commissions and institutions working for protection/ conservation of natural resources (ZSI, BSI, BIS, Niti Ayog, etc.) • Green Justice network (Courts and specialised tribunals) • NGT Act 2010	3
Student Work - Review - Books, Scientific Journals, - Case studies - Group Discussions, etc	20

Suggested Readings:

1. Divan S. & Rosencranz A., Environmental Law and Policy in India. OUP, 2001.
2. Naseem M., Environmental Law in India Mohammad. Kluwer Law, 2011 International.
3. Venkat A. Environmental Law and Policy. PHI, 2011
4. Sands P., Peel J., Principles of International Environmental Law, CUP 2018
5. Abraham C.M. Environmental Jurisprudence in India. Kluwer Law International. 1999.
6. T S Doabia. 2017. Environmental and Pollution Laws in India. 3rd Edition. Publisher: Lexis Nexis
7. P. Leelakrishnan. 2016. Environmental Law in India. 4th edition. Publisher: Lexis Nexis.
8. S. K. Mohanty. 2014. Environment & Pollution Laws – Universal Law Publication.

EVS 303 MJE - Environmental Geosciences	
Topics	**Lectures**
Geosciences: Definition, branches, applications	2
Fundamentals of Earth System: Origin of Universe (Big Bang Theory), Solar system, Earth and Moon. Meteorites-types and origin. Cosmic abundance of elements, Distribution of elements in solar system and in Earth. Formation and characteristics of Earth Systems (Atmosphere, Lithosphere, biosphere and hydrosphere).	5
Earth structure: Structure of the Earth (Mechanical layers of earth), Geothermal gradients. Earth's magnetic and gravitational fields (origin and effects). Dynamic nature of earth (Plate Tectonics, Mountain building, earthquakes, volcanoes.	5
Earth's Composition: Minerals (Definition, characteristics, classification, basic rock forming minerals); Rocks (Definition, classification, rock cycle)	6
Surface Processes & Landforms: Processes (Physical, chemical, biological) and agents of weathering, erosion, transportation and deposition, products of weathering; Erosional and depositional landforms: Glacial, Aeolian, Fluvial, Coastal, shallow marine and deep marine.	4
Soil: Genesis of Soil; Lateritisation; Soil Profile; Soil texture, structure; Bio-, Physico-, Chemical properties of soil; Soil Classification; Fertility; Land use and Land capability classification; Water-logging, salinization, desertification and degradation of soil.	6

Earth's natural resources: Occurrence and paragenesis of metallic, non-metallic minerals (metallic: Iron, manganese, copper, zinc, noble metals etc.; non-metallic: silica, asbestos, mica, carbonates, evaporites etc., coal, oil and natural gas). Surface and groundwater resources, Hydrological cycle.	6
Geomorphology: Landforms related to various agents (wind, ice, Water- fluvial, coastal and oceanic). Drainage types and density, Stream ordering, Hypsometric analyses.	6
Elements of Geological mapping: Geological mapping, Introduction to Toposheets, concept of scale, types of geographic projections, Representing lithological and structural elements on maps	4
Introduction to Applied Environmental Geology Land-use planning, Land reclamation, watershed management, etc.	3

Suggested Reading:

1. The Earth System (3rd Edition) 3rd Edition- Lee R. Kump, James F. Kasting, Robert G. Crane.
2. Environmental Geology – K.S. Valdiya
3. Plate Tectonics & Crustal Evolution- Kent. C. Condie, 1997
4. A.D. Howard and I Remson : Geology in Environmental Planning
5. Todd, D.K.: Groundwater Hydrology.
6. Davis S.N. and Dewiest R.J.M.: Hydrogeology.
7. Textbook of Soil Science- T.D. Biswas and S.K. Mukherjee
8. The Nature and Properties of Soils, 14th Edition Nyle C., Brady and Ray R. Weil
9. Cesare Emiliani. Planet Earth: Cosmology, Geology, and the Evolution of Life and Environment.
10. G.R. Thompson, & J. Turk. 1998.Introduction to Physical Geology.
11. A.D. Howward and I Remson : Geology in Environmental Planning.
12. T.D. Biswas and S.K. Mukherjee. Textbook of Soil Science.
13. Nyle C., Brady and Ray R. Weil.The Nature and Properties of Soils, 14th Edition
14. Holmes' Principles of Physical Geology 4th ed. 1993 Edition- Arthur Holmes (Ed) P. Mc L. D. Duff
15. D. Burrbank & R. S. Anderson. 2012.Tectonic Geomorphology
16. Umeshwar Prasad. Economic Geology: Economic Mineral Deposits 2nd Ed.

EVS 304 MN - Water & Waste Water Management	
Topic Details	**Lectures**
Quantity & Quality of water - Water Requirements for various purposes [e.g. Domestic, Commercial and Industrial. Variation in quantity of water and waste water, Factors affecting rate of demand.	4
Water Sources – Availability & quality of surface water & ground water. quality of raw water. (River zonation with reference to developmental activity)	2
Impact of future growth and development and change in quality of life on water requirements. Need of water quality standards for domestic & industrial purpose. Specifications for drinking water (physical, chemical & bacteriological) by Bureau of Indian Standards & World Health Organization.	2
Fresh Water Treatment - Primary, secondary and Tertiary treatment process. - Advanced treatment methods e.g. Demineralization; Ultra filtration; Reverse osmosis; other membrane filtration systems, etc. - Supercritical water oxidation. - Recent Advancements in Water & Waste water treatment	10
Waste Water Treatment - Primary, secondary and Tertiary treatment process including Biological Treatments - Advanced treatment methods e.g. Demineralization; Ultra filtration; Reverse osmosis; other membrane filtration systems, etc. - Sludge Treatment and Disposal - Supercritical water oxidation. - Recent Advancements in Water & Waste water treatment	10
Introduction to Parameters of Water & Waste Water Engineering & Design Criteria	5
Overview of National River Action Plan	2
Student Work - Review - Books, Scientific Journals - Visit to water & Waste Water treatment Plants, Industries, etc.	10

Suggested Readings:

1. Garg S.K., Water Supply Engineering (Vol-I & II), Khanna Publishers
2. Peavy H.S., Rowe D.R. & Tchobanoglous G., "Environmental Engineering". McGraw Hill International Edition.

3. Karia G.L., Wastewater Treatment: Concepts and Design Approach, PHI, 2013.
4. Metcalf & Eddy, "Wastewater Engineering- Treatment and Reuse," Tata McGraw Hill, 4th Edn., 2003.
5. Rangwala. Water supply and sanitary engineering.
6. K.N. Duggal. Elements of Environmental Engineering
7. G. S. Birdie and J. S. Birdie. Water Supply and Sanitary Engineering
8. McGhee T. J., "Water Supply and Sewerage", McGraw-Hill, Inc., 1991.
9. Davis M. L. & Cornwell D. A., "Introduction to Environmental Engineering", McGraw-Hill, Inc.,1991.
10. Sawyer C. N., McCarty P. L., Parkin G. F., "Chemistry for Environmental Engineers", McGraw-Hill, 1994.
11. Punmia B.C., Environmental Engineering (Vol-I & II), Laxmi Publishers.

EVS 341 VSC: Energy and Environment	
Topic Details	**Lectures**
• Introduction (Sources of energy and their classification; Energy forms and transformation. Energy requirement, Usage patterns)	4
Fossil Fuels • Classification, composition, physiochemical characteristics; • Energy content of coal, petroleum and natural gas; • Formation, reserves, exploration/ mining and uses of Coal, Oil and Natural gas; • Environmental problems associated with exploration / mining, processing, transportation and uses	4
Nuclear energy Fission and fusion, Nuclear fuels, – Mining and processing of Uranium –concentration, refining, enrichment, fuel fabrication and fuel cycle; Nuclear reactors and radioactive waste; Environmental implications.	4
Renewable Energy - Hydal; Solar; Wind; Geothermal; Bioenergy • Sources & Potentials in India, • Methods of Energy Harnessing / extraction, • Methods of usage/storage • Energy conservation measures • Environmental Implications	4

Energy & Climate Change • Current energy infrastructure (Global & Indian context) • Future technologies: carbon sequestration, biofuels, hydrogen fuel cells, etc. • Impacts on the environment;	2
Student Work • Case Studies • Review - Books, Scientific Journals • Group Discussions, etc • Field Visit	12

Suggested Readings

1. Renewable Energy – Environment and Development: M. Dayal; Konark Pub. Pvt. Ltd.
2. Alternative Energy: S. Vandana; APH Publishing Corporation
3. Nuclear Energy – Principles, practice and prospects: S. K. Agarwal; APH Publishing Corporation
4. Bio-Energy Resources: Chaturvedi; Concept Pub.
5. National Energy – policy, crisis and growth: V S. Mahajan; Ashis Publishing House
6. Geography and Energy – Commercial energy systems and national policies: J.D. Chapman

Suggested readings:

1. Lutgens & Tarbuck. The Atmosphere.
2. Cunningham & Cunningham. Fundamentals of Environmental Science: A Global Concern.
3. Chew S.C., The recurring dark ages: ecological stress, climate changes, and system transformation. Rowman Altamira, 2006.
4. William F. Ruddiman. Earth's Climate: Past and Future.
5. IPCC Reports on Climate Change

EVS 305 MN (P) - Environmental Chemistry – LAB

1. Green Synthesis of the following compounds: adipic acid, catechol, disodiumc iminodiacetate (alternative to Strecker synthesis)

2. Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols; microwave assisted reactions in organic solvents: Diels-Alder reaction and Decarboxylation reaction,
3. Ultrasound assisted reactions: sono-chemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)
4. Green Counterpart of common organic reactions: Aldol, Friedel-Crafts, Michael, Knoevenagel, Cannizzaro, benzoin condensation and Dieckmann condensation,
5. Rearrangement Reaction by Green Approach: Fries rearrangement, Claisen rearrangement, Beckmann rearrangement, Baeyer-Villiger oxidation.
6. Alkalinity Test; Turbidity Test; pH and Conductivity Test;
7. Estimation of Hardness; Estimation of BOD and COD; Estimation of residual chlorine.
8. Rock forming minerals – Hand specimens
9. Ore Minerals – Hand specimens
10. Identification of rocks – Igneous, Sedimentary, metamorphic
11. Geomorphology – Drainage Pattern, types, etc.
12. Soil Classification
13. Sampling and analysis of organic matter, nitrate, sulphate, TDS and COD of waste water/ contaminated soil.

Optional

1. Field Visit to a water treatment site, sampling, analysis, and reporting on the same;
2. Visit to a STP or ETP site and reporting
3. Field visits to Chemical Industry.

EVS 331 RP/ FP/ OJT – Field project/ Industrial training/ Project:

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students will be assigned to the on campus faculty/ research scientists from various national research institutes such as NCL/ IISER/ IITM etc/ experts from NGOs working in environmental field/others; under whose guidance he or she would work on a problem keeping the focus to enhance their own ability to critical thinking, identification of research problems and research gaps, formulate research objectives, formulation of research plan, and problem solving via execution of specific experiments, and develop specialized skills to handle specific problems. This would train the students to nurture their creativity and innovative ideas,

collaboration/teamwork and leadership, communications, learning self-reliance and project management.

Adequate assessment requirements for individual marking are presentations with discussions and seminars on the working process and the results.

Syllabus Details – Semester VI

EVS 351 MJ - Environmental Impact Assessment (EIA) & Risk Analysis (Theory & Practical)	
Topic Details	**Lectures**
Introduction	2
Sustainable Development challenges and need for EIA. Definition, aims and objectives of EIA. Concepts of EIA and Scope of EIA. Evolution of EIA. Benefits and Drawbacks of EIA process.	
Legislation and Procedures	2
EIA notification 2006 and other legislative requirements and administrative procedures India and its implementation, in India. Accreditation of EIA consultants by Quality Control of India – NABET requirements and guidelines.	
Assessing Environmental Impacts: The EIA Approach	8
- EIA as a planning process: developmental plans, policies and strategies for developmental projects - Steps in EIA process, - Impact Assessment methodologies - Identification, Prediction and assessment of impacts - Public Participation (PP) - Preparing an EIA report /Environmental Impact Statement (EIS)	
Case Studies	5
Introduction to Strategic Environmental Assessment (SEA)	1
Risk Assessment	3
- Intro to Risk Assessment & concepts of risk analysis - Logic trees - Intro to international standards	
Eco-toxicology	2
Introduction to toxicology, Principles of toxicology with reference to Environment, scope of toxicology. Concepts of Toxicology: Exposure, Dose Response Relationships, TLM and Lethality Studies. Biochemical basis toxicity – mechanism of toxicity and receptor mediated events, acute and chronic toxicity.	

Toxicants in the Environment	2
Toxic substances in the environment, its types, their sources and entry routes. Transport of toxicants by air, soil and water: transport through food chain - bioaccumulation and biomagnifications of toxic materials in food chain.	
Effects and Evaluation of Toxicity	2
Classification, Methods of assessment, Types of Bioassay, bioassay test models and classification, Threshold Limit Value (TLV), LC_{50}, LD_{50}, toxicity testing: lethal, sub-lethal & chronic tests.	
Student work / Practical	
• Reconnaissance surveys, • Field work for collecting baseline data, assessment of alternatives • Assignments / Tutorials • Reviews of various reports, books • Presentations	18

Suggested Reading:

EIA

1. Judith, P. Handbook of Environmental Impact Assessment. Blackwell Science. 1999.
2. Marriott, B. Environmental Impact Assessment: A Practical Guide. McGraw-Hill, New York, USA. 1997.
3. Larry W. Canter. Environmental Impact Assessment. McGraw Hill, Inc, New York
4. Y. Anjaneyulu and Valli Manickam. Environmental Impact Assessment Methodologies. BSP publications, Hyderabad.
5. Morgan, R. K. (1998). Environmental impact assessment: a methodological perspective. Springer Us.
6. Paliwal, R. (2006). EIA practice in India and its evaluation using SWOT analysis. Environmental Impact Assessment Review, 26(5), 492–510.
7. The environment (Projection) Act 1986
8. The Environmental Impact Assessment Notification, 1994, GoI
9. Environmental Impact Assessment Notification, 2006
10. Environmental Impact Assessment Notification, 2020 (draft)

Risk Assessment / Toxicology:

1. Shaw I.C. and Chadwick J. Principles of Environmental Toxicology, Taylor & Francis, 2008
2. Ming-Ho Yu, Humio Tsunoda, Masashi Tsunoda. (2011). Environmental Toxicology: Biological and Health Effects of Pollutants, 3rd Edition, CRC Press.

3. Stephen M. Roberts, Robert C. James, Phillip L. Williams (2015). Principles of Toxicology: Environmental and Industrial Applications. 3rd Edition, Wiley Publishers.
4. N Plant. (2003) (eds). Molecular Toxicology Taylor & Francis Publishers.
5. SataKe M, Mido Y, Yasuhisa H, Taguchi S, Sethi MS (2013) (eds). Environmental Toxicology Discovery Publishing House, India.
6. Subramanian MA (2010) (eds). Toxicology: Principles and Methods MJP Publishers, India.

EVS 352 MJ - Environmental Biotechnology	
Topic Details	**Lectures**
Introduction & Basic concepts Definitions, scope of environmental biotechnology, applications in environmental resource conservation, sustainability, cleanup/bioremediation, biodegradation, transgenics/genetic engineering	5
Environmental Microbiology - Microbes in Environment - Biotransformation and Biodegradation	6
Biotechnological Tools and Techniques - Background, scope, various biotechnological tools and their significance for environmental analysis - Basics of microbial, plant and animal tissue culture techniques	5
Basics of recombinant DNA technology DNA/RNA, molecular cloning, Gene cloning Vehicles- vector: plasmids, cosmids, phage vectors- λ and M13, YACs, BACs, expression vectors, Agrobacterium vectors, host – properties of host	5
Enzymes for recombinant DNA technology Restriction enzymes, ligases, polymerases, alkaline phosphatase.	4
Transformation Techniques of introducing DNA in bacteria, animal and plant cells Selection of transformants & characterization	4
Polymerase chain reactions (PCR) and modifications	3
DNA sequencing techniques Maxam-Gilbert's method, Sanger's Dideoxy method, Automated DNA sequencing, Next generation sequencing	3

Biotechnology for Environment	
Concepts and applications Environmental Biotechnology of Bioremediation (including Phytoremediation), Biopesticides, Bio-composting, Biomining, Bio-methanation, Bioleaching, Biosensors, etc.	7
GMOs and environment, International Conventions & Policies, biosafety and regulations, risks associated with production and release of GMOs- risk assessment, ways to reduce risks	3

Suggested Reading:

1. Jördening, H.J. and Winter, J. eds., Environmental biotechnology: concepts and applications. John Wiley & Sons, 2005.
2. Singh, B.D. and Singh, B.D., Biotechnology expanding horizons. Kalyani publishers. 2007.
3. Lehninger, A.L., Nelson, D.L., Cox, M.M., Lehninger principles of biochemistry. Macmillan, 2005.
4. Elliott, W.H., Elliott, D.C. and Jefferson, J.R., Biochemistry and molecular biology (Vol. 2001, p. 586). Oxford: Oxford University Press, 1997.
5. Wang, L.K., Ivanov, V., Tay, J.H. and Hung, Y.T. eds., Environmental biotechnology (Vol. 10). Springer Science & Business Media, 2010.
6. Rittmann, B.E. and McCarty, P.L., Environmental biotechnology: principles and applications. Tata McGraw-Hill Education, 2012.
7. Patel A.H., Industrial microbiology. Macillan India Ltd, 2000.
8. Nalwa, H.S. ed., Nanostructured materials and nanotechnology: concise edition. Elsevier, 2001.
9. Doble, M., Kruthiventi, A.K. and Gaikar, V.G., Biotransformations and bioprocesses. CRC Press, 2004.
10. Hambleton, P., Melling, J. and Salusbury, T.T. eds., Biosafety in industrial biotechnology. Glasgow: Blackie Academic & Professional, 1994.
11. A. H. Scragg, Alan H. Environmental Biotechnology: Oxford University Press
12. Martin Alexander. Biodegradation and Bioremediation: Academic Press.

13. Kirsten Heimann, Obulisamy Parthiba Karthikeyan, Subramanian Senthikannan Muthu, Environmental Footprints and eco-design of Products and Processes: Biodegradation and Bioconversion of Hydrocarbons. Springer.
14. Wang-Yu-Tong, Xue-Cheng Zhang, Shan-Qun Jiang, Xiang Dong. Integrated Biotechnology: Fundamentals and Applications. Stadium Press.
15. Neil Willey, Phytoremediation: Methods and Reviews. Humana Press.
16. John M.s. Barllett, David Stirling, PCR Protocols, Humana Press.

EVS 353 MJE - REMOTE SENSING AND GIS	
Topic	**Lectures**
UNIT 1: Remote sensing - Introduction, History Of RS, Components - EMR spectrum, Active and passive remote sensing, Atmospheric windows - Types of remote sensing: Optical, Thermal, Microwave, Hyperspectral, RADAR, LIDAR - Resolution of Remote sensing data: Spatial, Spectral, Radiometric and Temporal - Interaction of EMR with the earth's surface and atmosphere: Energy response mechanism: Reflection, Absorption, Transmission, Scattering, Refraction, Reflectance, Emission and scattering - Spectral reflectance curve for vegetation, soil, water - Types of platforms, Geostationary orbit and Sun-synchronous Polar orbit - Multi spectral scanning, Scanning Systems (Push broom and Whiskbroom etc) - Indian remote sensing and sensors	15
UNIT 2: GIS - Introduction, History Of GIS, Components - Shape of Earth-Geoid Spheroid Ellipsoid - Datum and projections: Conical, Azimuthal and Cylindrical. LCC Projection, UTM and Polyconic projections. Types of Datum. - Types of GIS data: Spatial, Attribute; Vector-point, line, polygon, Raster - Data structures in GIS: Spatial: Raster data, Vector data, comparative overview. Non-spatial data - Hierarchical, Network and relational data. - Acquisition of spatial data: Scanning, Geo referencing, concept of layer, digitizing, error detection and correction, concept of topology. - Spatial Analysis: Vector based: Overlays operations, point in polygon, line in	15

polygon, polygon in polygon; single layer operations and Multilayer operations. - Raster based: Buffering, Network Analysis, generation of Thematic maps.	
UNIT 3: Applications in RS and GIS - Aerial photography: Basic geometric characteristics of aerial photographs, Photo interpretation elements for visual interpretation - Satellite image processing and interpretation: Factors governing Interpretability, Elements of image interpretation. Image correction, rectification techniques. - Remote sensing products widely used and their features-sensors, uses, etc: LANDSAT, CARTOSAT, LISS, etc. - Global Positioning System (GPS), GLONASS, GAGAN: principles, applications - DEM, DTM, Terrain Analysis - RS GIS applications: Landuse - land cover changes; Natural hazards and hazard management; hydrology; monitoring water quality and soil quality; geology, forestry, agriculture, etc. - Use of GIS to represent environmental status and highlight environmental issues. - Latest trends in RS GIS: web GIS, drone mapping and surveying, wearable GIS, LIDAR	15

Suggested Reading:

1. Lillesand T. M., Keifer, R. W. & Chipman. Remote Sensing and Image Interpretation. John Wiley, 7th Edition, 2015
2. Burrough P.A. and McDonnell R.A., Principles of Geographical Information Systems. 2nd Edition, Oxford University Press, 2006.
3. Joseph G. (2003): Fundamentals of Remote Sensing, Universities Press, Hyderabad.
4. Haywood, Ian (2000): Geographical Information Systems, Longman
5. Chang, Kang-taung (2002): Introduction to Geographic Information Systems, Tata McGraw-Hill.

6. Gupta, R. P. 2003. Remote sensing geology, Springer, New York
7. Ramsay : Trends in Geological Remote Sensing
8. Pandey : Photogeology
9. Paine D.P.: 1981, Aerial Photography and Image Interpretation for Resource Management, John Wiley and Sons, New York, 571 p.
10. Jense J. R., Remote Sensing of the Environment – An earth resource perspective. Pearson Education, 2nd Edition, 2013

EVS 354 MN - Solid Waste Management	
Topic	**Lectures**
Introduction Definitions, Historical development, Source and type-based classification, chemical and physical composition, Factors affecting solid waste management: Climate, financial, cultural constraint, quality and quantity of waste. Environmental and health impacts due to solid waste and handling of it. Characterization: physical & chemical characteristics, implications for solid waste management.	6
Municipal Solid Waste, Industrial Solid Waste, Hazardous Waste, Biomedical & E-waste: Generation, Collection, segregation, Transportation	8
Treatments and disposal characterization, UN classification, Waste processing, Recovery of biological and chemical conversion products composting, bio-methanation, RDF system, hydrolysis, Pyrolysis, plasma gasification, incineration, sanitary landfills.	4
Introduction to Solid Waste Management Rules (Solid Waste Management Rules, 2016; Plastic Waste Management Rules 2016; Biomedical Waste Management Rules 2016, etc.)	4
Case Studies	8
Student work - Assignments / Tutorials - Reviews of various research papers, reports, books - Presentations - Field Visits	15

Suggested Readings

1. M.S. Bhatt and Asheref Illiyan. 2012. Solid Waste Management: An Indian Perspective.

2. S. Bhatia. 2007. Solid and Hazardous Waste Management. Atlantic publication.
3. Goel, Sudha (Ed.). 2017. Advances in Solid and Hazardous Waste Management
4. M.N.Rao & Razia Sultana. Solid and Hazardous Waste Management
5. M.N. Rao, Razia Sultana,**Sri Harsha Kota,** Anil Shah, **Naresh Davergave. 2016. Solid and Hazardous Waste Management: Science and Engineering. 1st Edition. Butterworth-Heinemann publi**cation.
6. Handbook of Solid Waste Management, by George Tchobanoglous & Frank Kreith, 2nd Edition, Publisher McGRAW-HILL. DOI: 10.1036/0071356231
7. Integrated Solid Waste Management: Engineering Principles and Management Issues First Edition by George Tchobanoglous (Author), Hilary Theisen (Author), Samuel Vigil (Author). ISBN-13: 978-0070632370
8. Handbook of Solid Waste Management and Waste Minimization Technologies. 2002. by, Nicholas P Cheremisinoff Hardcover ISBN: 9780750675079
9. Industrial Waste Treatment Handbook. 2005. by Woodard & Curran, Inc. Hardcover ISBN: 9780750679633 Paperback ISBN: 9781493303199
10. Thermal Processing of Wastes 2010 By J. C. Jones ISBN: 978-87-7681-590-5
11. Transport and Chemical Rate Phenomena.1995. [Hardcover] By N. Themelis. Publisher: Taylor & Francis (July 17, 1995) ASIN: B00SB1MD32
12. Waste Management Practices - Municipal, Hazardous, and Industrial. 2014. By John Pichtel. ISBN - 13: 978-1-4665-8519-5
13. Industrial Waste Management Hardcover 2017 by Zander Ellis (Editor). ISBN-13: 978-1635491494.
14. Manual on Municipal Solid Waste Management, CPHEEO, Ministry of Urban Development, Govt. of India, New Delhi, 2000.
15. White P.R. et al, Integrated Solid Waste Management, Lewis Publisher, 1989.
16. David L.H.F. and Liptak D. G., Hazardous waste and solid waste, Lewis Publisher, 2000
17. Oberoi N.K, Environmental Management, (2nd Edition) Excel Books, New Delhi, 2003.

EVS 391 MJ: Environmental Economics	
Topic Details	**Lectures**
Basics of Environmental Economics • Overview of environmental problems in India • What is environmental economics – Interlinkages between the economy and the environment. • Economic aspects of making Environmental Policy.	2

Introduction to Economic Instruments • Regulatory tools versus Incentives and Subsidies. • Charges/Taxes; Subsidies; Deposit-refund systems; Market Creation; Enforcement incentives, etc. • Effectiveness of economic instruments.	3
The Theory of Externalities • Pareto optimality and market failure in the presence of externalities; property rights and the Coase theorem.	4
Overview to the Design and Implementation of Environmental Policy • Pigouvian taxes and effluent fees; tradable permits; choice between taxes and quotas under uncertainty; implementation of environmental policy	3
International Environmental Problems Trans-boundary environmental problems; economics of climate change; trade and environment.	2
Introduction to the measuring of Benefits of Environmental Improvements Non-market values and measurement methods; risk assessment and perception.	2
Sustainable Development Concepts; measurement.	2
Student Work • Case Studies • Review - Books, Scientific Journals • Group Discussions, etc.	6

Suggested readings:

1. John V. Krutilla; Anthony C. Fisher.1985. The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources. The Johns Hopkins Press.
2. Alan Gilpin. 2000. Environmental Economics: A Critical Overview. Wiley.
3. Hanley, Nick, Jason F. Shogren& Ben White: Environmental Economics in Theory and Practice, New Delhi: Macmillan –India, 1997.
4. James, D.E., Economic Approaches to Environmental Problems: Techniques and Results of Empirical Analysis, Elsevier Scientific Publishing Co., 1978.
5. Nash, R.F., The Rights of Nature: A History of Environmental Ethics, University of Wisconsin, 1989.
6. Whytte, Anne, V. and Ian Burton (eds), Environmental Risk Assessment, John Wiley &

Sons, 1980.
7. Arrow, K.J. and Scitovsky, T., Readings in Welfare Economics Part III, 1969.
8. Coase, R.H., The Problem of Social Cost in Readings in Micro Economics by Breit and Hochman, 1951.
9. Allen V. Kneese and James L. Sweeney, eds. Handbook of Natural Resource and Energy Economics, Chapters 2,12,14,17, North Holland, 1985.
10. Fisher, A.C., Environment and Resource Economics, Selected readings, New Horizon in Environmental Economics, Ed. W.E. Oates, 1995
11. Oates, W.E., Economics of the Environment, 1992.
12. Field, B.C., Environmental Economics: An Introduction, McGraw Hill, 1994
13. Baumol, W.J. and W.E. Oates, `The Theory of Environmental Policy', Cambridge University Press, 1988.
14. Bohm, P. and Russell, C., `Comparative Analysis of Alternative Policy Instruments'
15. Handbook of Natural Resource and Energy Economics, Vol.I Ed. A.V. Kneese and J.L. Sweeney, 1985.
16. Mehta, S., S. Mundle and U. Sankar, `Incentives and Regulation for Pollution Control', Sage, 1997.
17. Sankar, U. (ed.) Environmental Economics, New Delhi: Oxford University Press, 2001.

Suggested Reading:

1. Bell F.G., Geological Hazards: Their Assessment, Avoidance & Mitigation, Taylor and Francis, 2003.
2. Alexander D., Natural Disasters, ULC press Ltd, London, 1993.
3. Bryant E., Natural Hazards, 2nd Edition, Cambridge University Press
4. B. Narayan. Disaster Management - APH Publishing Corporation
5. Chakrabarty U.K. Industrial Disaster Management - Asian company, new Delhi
6. Peter K. Lagoy. Risk Assessment- An Environmental Perspective - Jaico Publishing House, Mumbai
7. National Policy on Disaster Management, NDMA, New Delhi, 2009.
8. A Global Report - Reducing Disaster Risk, A Challenge for Development; UNDP Publication, 2004
9. Websites of Government of India (e.g. https://ndma.gov.in/en/ , etc.)

EVS 332 RP - Project/ Dissertation/ OJT/ FP:

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students will be assigned to the on campus faculty/ research scientists from various

national research institutes such as NCL/ IISER/ IITM etc/ experts from NGOs working in environmental field/others; under whose guidance he or she would work on a problem keeping the focus to enhance their own ability to critical thinking, identification of research problems and research gaps, formulate research objectives, formulation of research plan, and problem solving via execution of specific experiments, and develop specialized skills to handle specific problems. This would train the students to nurture their creativity and innovative ideas, collaboration/teamwork and leadership, communications, learning self-reliance and project management.

Adequate assessment requirements for individual marking are presentations with discussions and seminars on the working process and the results.

3rd Year Physics

FIFTH SEMESTER							
Course Code	**Title of the Course**	**Credits**	**Theory**	**Practical**	**CIA**	**ESE**	**Total**
PHY 301 MJ	Classical Mechanics	4	4	-	50	50	100
PHY 302 MJ	Quantum Mechanics	4	4	-	50	50	100
PHY 303 MJE	Solid State Physics	4	4	-	50	50	100
PHY 304 MN	Electrodynamics	4	4	-	50	50	100
PHY 341 VSC	Introduction to Astrophysics	2	2	-	25	25	50
PHY 305 MN (P)	Physics Lab I	2	-	2	25	25	50
PHY 331 RP	Graduate Level Thesis	2	-	2	25	25	50
	Total	22	18	4	325	325	650

SIXTH SEMESTER							
Course Code	**Title of the Course**	**Credits**	**Theory**	**Practical**	**CIA**	**ESE**	**Total**
PHY 351 MJ	Statistical Mechanics	4	4	-	50	50	100
PHY 352 MJ	Subatomic Physics	4	4	-	50	50	100
PHY 353 MJE	Atomic and Molecular Spectroscopy and Lasers	4	4	-	50	50	100
PHY 354 MN	Digital and analog electronics	4	4	-	50	50	100
PHY 391 MJ	Renewable Energy and Energy Harvesting	2	2	-	25	25	50
PHY332 RP	Graduate Level Thesis	4	-	4	25	25	50
	Total	22	18	4	325	325	650

SEMESTER V

PHY 301 MJ: Classical Mechanics

This course extends knowledge of fundamental thermal physics principles and introduces the powerful and elegant Lagrangian and Hamiltonian formulations of classical mechanics

PHY 301 MJ: Classical Mechanics – 4 Credits	
Central force Problem	**No. of Lectures**
Nature of orbits in an attractive inverse square field	3
Kepler's laws of planetary motion. Rutherford scattering as an example of repulsive potential.	3
Mechanics of Ideal Fluids	**No. of Lectures**
Streamlines and flow lines; Equation of continuity; Euler's equation of motion;	3
Streamline motion - Bernoulli's equation and its applications. Definition of Newtonian and non-Newtonian fluids	3
Lagrangian and Hamiltonian formulation of Classical Mechanics	10
Generalized coordinates, constraints and degrees of freedom; D'Alembart's principle;	2
Lagrange's equation for conservative systems (from D'Alembert's principle; variational principle not required) and its application to simple cases	4
Generalized momentum; Idea of cyclic coordinates, its relation with conservation principles;	4
Definition of Hamiltonian, Hamilton's equation (derivation by Legendre transformation) and its application to simple cases.	4

REFERENCE BOOKS:

- Mechanics: C. Kittel, W.D. Knight, M.A. Ruderman, C.A. Helmholz and B.J.Moyer (2008) Berkeley Physics Vol 1, Tata McGraw-HillLtd
- Classical Mechanics: N. Rana and P. Joag (2001) Tata McGraw-HillEducation
- Classical Mechanics: J.R. Taylor (2005) University ScienceBooks
- Feynman Lectures in Physics, Vol I, Addison-Wesley.
- Classical Mechanics: H. Goldstein, C. Poole and J. Safko (2002) 3rd edition, Pearson
- Classical Dynamics of Particles and Systems: Thornton and Marion (2003)Thomson Learning EMEA Ltd

PHY 302 MJ: Quantum Mechanics

Quantum mechanics plays a central role in our understanding of fundamental phenomena, primarily in the microscopic domain. It lays the foundation for an understanding of atomic, molecular, condensed matter, nuclear and particle physics.

PHY 302 MJ: Quantum Mechanics – 4 Credits	
Time dependent and time independent Schrodinger equation	**No. of Lectures**
Eigenstates, normalization and orthonormality.	6
Simple applications of Quantum Mechanics	**No. of Lectures**
One dimensional potential well and barrier, boundary conditions, bound and unbound states.	2
Reflection and transmission coefficients for a rectangular barrier in one dimension – explanation of alpha decay.	4
Free particle in one dimensional box, box normalization, momentum eigen functions of a free particle	4
Linear harmonic oscillator, energy eigenvalues from Hermite differential equation, wave function for ground state, parity of wave function.	2
Schrodinger equation in spherical polar coordinates	**No. of Lectures**
Angular momentum operators and their commutation relations;	2
eigenvalues and eigen functions of L2 and Lz; theorem of addition of angular momenta [statement with examples].	6
The hydrogen atom problem – stationary state wave functions as simultaneous eigen functions of H, L2, and Lz;	5
radial Schrodinger equation and energy eigenvalues [Laguerre polynomial solutions to be assumed]; degeneracy of the energy eigenvalues.	5

REFERENCE BOOKS:

- Quantum Physics: S. Gasiorowicz (2003) 3rd edition, Wiley IndiaEdition
- Quantum Physics: E.H. Wichman (2008) Berkeley Physics Course, Vol 4, Tata McGraw-Hill Ltd
- Introduction to Quantum Mechanics, David J. Griffiths, PearsonEducation
- Introductory Quantum Mechanics, Richard Liboff, Addison-Wesley; 4edition
- A Modern Approach to Quantum Mechanics, John Townsend, VivaBooks
- Principles of Quantum Mechanics: R. Shankar (2010) 2nd edition,Springer

PHY 303 MJE: Solid State Physics

Solid State Physics explains how the macroscopic properties of solids result from atomic scale properties. Solid State Physics forms the theoretical basis of Materials Science

PHY 303 MJ: Solid State Physics – 4 Credits	
Crystal Structure	**No. of lectures**
Crystalline and amorphous solids, translational symmetry	2

Elementary ideas about crystal structure, lattice and bases, unit cell, reciprocal lattice	3
fundamental types of lattices, Miller indices, lattice planes, simple cubic, f.c.c. and b.c.c. lattices	5
Laue and Bragg equations. Determination of crystal structure with X- rays.	2
Elementary band theory	**No. of lectures**
Kronig Penny model. Band Gap. Conductor, Semiconductor (P and N type) and insulator. Conductivity of Semiconductor, mobility, Hall Effect. Measurement of conductivity (04 probe method) & Hall coefficient. Effect of concentration and temperature on fermi level.	6
Dielectric properties of materials	**No. of lectures**
Electronic, ionic and dipolar polarizability, local fields, induced and oriented polarization – molecular field in a dielectric; Clausius-Mosotti relation.	4
Magnetic properties of materials	**No. of lectures**
Dia, para and ferro-magnetic properties of solids. Langevin's theory of diamagnetism and paramagnetism. Quantum theory of paramagnetism, Curie's law. Ferromagnetism: spontaneous magnetization and domain structure; temperature dependence of spontaneous magnetisation; Curie- Weiss law, explanation of hysteresis.	8
Superconductivity	**No. of lectures**
Introduction (Kamerlingh-Onnes experiment), effect of magnetic field, Type-I and type-II superconductors, Isotope effect. Meissner effect. Heat capacity. Energy gap. Ideas about High-Tc superconductors	5

REFERENCE BOOKS:

- Solid State Physics: N.W. Ashcroft and N.D. Mermin (1976) College edition, Harcourt College Publishers
- Introduction to Solid State Physics: C. Kittel (2004) 8th edition, John Wiley and Sons
- Atomic and Electronic Structure of Solids, E. Kaxiras; Cambridge University Press.

PHY 304 MN: Electrodynamics

Introduction to electrodynamics and a wide range of applications including communications, superconductors, plasmas, novel materials, photonics and astrophysics

PHY 304 MJ: Electrodynamics – 4 Credits	
Generalization of Ampere's Law	**No. of lectures**
Displacement Current, Maxwell's Field Equations, Wave equation for electromagnetic (EM) field and its solution	4
plane wave and spherical wave solutions, transverse nature of field, relation between E and B; energy density of field, Poynting vector and Poynting's	4

theorem, boundary conditions	
EM Waves in an isotropic dielectric	**No. of lectures**
Wave equation, reflection and refraction at plane boundary, reflection and transmission coefficients	4
Fresnel's formula, change of phase on reflection, polarization on reflection and Brewster's law, total internal reflection.	4
EM waves in conducting medium	**No. of lectures**
Wave equation in conducting medium, reflection and transmission at metallic surface – skin effect and skin depth,	3
propagation of E-M waves between parallel and conducting plates – wave guides (rectangular only)	5
Dispersion	**No. of lectures**
Equation of motion of an electron in a radiation field : Lorentz theory of dispersion – normal and anomalous	2
Sellmeier's and Cauchy's formulae, absorptive and dispersive mode, half power frequency, band width.	6
Scattering	**No. of lectures**
Scattering of radiation by a bound charge, Rayleigh's scattering (qualitative ideas), blue of the sky, absorption.	4

REFERENCE BOOKS:

- Electricity and Magnetism: E.M. Purcell (2008) Berkeley Physics Course, Vol2, Tata McGraw-Hill Ltd
- Feynman Lectures on Physics: R.P. Feynman, R.B. Leighton and M. Sands (2011) The Millenium edition, Vol 2, Basic Books
- Introduction to Electrodynamics: D.J. Griffths (2012) Pearson Education
- Modern Electrodynamics: A. Zangwill (2013) Cambridge University Press

PHY- 341 VSC: ELECTIVE 1-Introduction to Astrophysics

The course defines and analyzes the basic concepts in astronomy. Describes the working principle of the telescope. Identifies important constellations – orient in space. Describes the planets of the solar system and their properties. Interprets the phenomena in the Universe. Describes and understand the physical processes in the Sun and other stars.

PHY 341 VSC: Introduction to Astrophysics – 2 Credits	
Astronomical Scales	**No. of lectures**

Astronomical Distance, Mass and Time, Scales, Brightness, Radiant Flux and Luminosity, Measurement of Astronomical Quantities Astronomical Distances, Stellar Radii, Masses of Stars, Stellar Temperature. Astronomical techniques: Basic Optical Definitions for Astronomy (Magnification Light Gathering Power, Resolving Power and Diffraction Limit, Atmospheric Windows), Optical Telescopes (Types of Reflecting Telescopes, Telescope Mountings, Space	4
Telescopes, Detectors and Their Use with Telescopes	**No. of lectures**
(Types of Detectors, detection Limits with Telescopes). The sun (Solar Parameters, Solar Photosphere, Solar Atmosphere, Chromosphere. Corona, Solar Activity, Basics of Solar Magneto- hydrodynamics. Helioseismology). The solar family (Solar System: Facts and Figures, Origin of the Solar System: The Nebular Model, Tidal Forces and Planetary Rings, Extra-Solar Planets.	6
Stellar spectra and classification Structure	**No. of lectures**
(Atomic Spectra Revisited, Stellar Spectra, Spectral Types and Their Temperature Dependence, Black Body Approximation, H R Diagram, Luminosity Classification)	2
The milky way	**No. of lectures**
Basic Structure and Properties of the Milky Way, Nature of Rotation of the Milky Way(Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the UGC Document on LOCF Physics 189 Galaxy and the Dark Matter, Nature of the Spiral Arms), Stars and Star Clusters of the Milky Way, Properties of and around the Galactic Nucleus.	6
Galaxies	**No. of lectures**
Galaxy Morphology, Hubble's Classification of Galaxies, Elliptical Galaxies (The Intrinsic Shapes of Elliptical, de Vaucouleurs Law, Stars and Gas). Spiral and Lenticular Galaxies (Bulges, Disks, Galactic Halo) The Milky Way Galaxy, Gas and Dust in the Galaxy, Spiral Arms	6

REFERENCE BOOKS

- Galaxies in the Universe: An Introduction: L.S. Sparke and J.S. Gallagher III(2000) Cambridge University Press
- Galactic and Extragalactic Radio Astronomy: G.L. Verschuur and K.I. Kellermann (1988) Springer-Verlag
- The Physics of Stars (Manchester Physics Series): A.C. Phillips (1999) John Wiley &Sons

PHY 305 MN (P): Physics Lab I - 2 Credits

1. Verification of Hall Effect.
2. Hysteresis Loop, coercivity, saturation magnetization.
3. Susceptibility of Paramagnetic Materials by Quincke's Tube method.
4. Michelson Interferometer with He-Ne Laser.
5. Characteristics of p-n Junction diode
6. Characteristics of transistor in forward and reverse bias.
7. Characteristics of Zener diode.

PHY 331 RP: Research Project / FP/ OJT - - 2 Credits

Combination of experimental and theoretical aspects of a problem. Perform experiment, collect data, analyze with various tools and software. Derive conclusion (positive or negative) from the work and summarize the report in form of dissertation in the VI semester

SEMESTER VI

PHY 351 MJ: Statistical Physics

Statistical mechanics, the microscopic basis of classical thermodynamics, is developed in this subject. It is one of the core areas of physics, finding wide application in solid state physics, astrophysics, plasma physics and cosmology. Using fundamental ideas from quantum physics, a systematic treatment of statistical mechanics is developed for systems in equilibrium

PHY 351 MJ: Statistical Physics- 4 Credits	
Microstates and macrostates	**No. of lectures**
Classical description in terms of phase space and quantum description in terms of wave functions.	1
Hypothesis of equal a priori probability for microstates of an isolated system in equilibrium. Interactions between two systems – thermal, mechanical and diffusive.	3
Statistical definition of temperature, pressure, entropy and chemical potential. Partition function of a system in thermal equilibrium with a heat bath	3
Classical statistical mechanics	**No. of lectures**
Maxwell-Boltzmann distribution law. Calculation of thermodynamic quantities for ideal monoatomic gases. Ergodic hypothesis and Liouville theorem and Ideal gases (monoatomic and diatomic): Translational, rotational, vibrational, electronic partition functions, thermodynamic functions	10
Motivations for quantum statistics	**No. of lectures**
Gibbs' paradox. Identical particle and symmetry requirement. Derivation of MB, FD and BE statistics as the most probable distributions (micro-canonical ensemble). Classical limit of quantum statistics.	6
Quantum statistical mechanics	**No. of lectures**
Bose-Einstein statistics: Application to radiation – Planck's law. Rayleigh Jeans and Wien laws as limiting cases, Stefan's law.	8
Fermi-Dirac statistics: Fermi distribution at zero and non-zero temperatures	7

REFERENCE BOOKS:

- Statistical Mechanics: K. Huang (1987) 2nd edition,Wiley
- Fundamental of Statistical and Thermal Physics: F. Reif (2008) Waveland PrInc
- Statistical Physics of Particles: Mehran Kardar (2007) Cambridge UniversityPress
- Statistical Physics- Reif-(2008)) Berkeley Physics Course, Vol 5, Tata McGraw-Hill Ltd

PHY 352 MJ: Subatomic Physics

This course intends to develop familiarity with the vast areas of nuclear and particle physics as well as develop an interest in these subjects. It also helps students acquire knowledge in the content areas of nuclear and particle physics, focusing on concepts that are commonly used in this area

PHY 352 MJ: Subatomic Physics -4 Credits	
Bulk properties of nuclei and Nuclear structure	**No. of lectures**
Nuclear mass, charge, size, binding energy, spin and magnetic moment. Isobars, isotopes and isotones; mass spectrometer. Nature of forces between nucleons, nuclear stability and nuclear binding, the liquid drop model (descriptive) and the Bethe-Weizsacker mass formula, application to stability considerations, extreme single particle shell model (qualitative discussion with examples)	2
Unstable nuclei and Nuclear Reactions	**No. of lectures**
Alpha decay : alpha particle spectra – velocity and energy of alpha particles. Geiger-Nuttal law. Beta decay : nature of beta ray spectra, the neutrino, energy levels and decay schemes, positron emission and electron capture, selection rules, beta absorption and range of beta particles, Kurie plot. Gamma decay : gamma ray spectra and nuclear energy levels, isomeric states. Gamma absorption in matter – photoelectric process, Compton scattering, pair production (qualitative)	2
Conservation principles in nuclear reactions. Q-values and thresholds, nuclear reaction cross-sections, examples of different types of reactions and their characteristics. Bohr's postulate of compound nuclear reaction, Ghoshal's experiment.	2
Nuclear fission and fusion	**No. of lectures**
Discovery and characteristics, explanation in terms of liquid drop model, fission products and energy release, spontaneous and induced fission, transuranic elements. Chain reaction and basic principle of nuclear reactors. Nuclear fusion: energetics in terms of liquid drop model.	6
Elementary particles	**No. of lectures**

Four basic interactions in nature and their relative strengths, examples of different types of interactions. Quantum numbers -mass, charge, spin, isotopic spin, intrinsic parity, hypercharge. Charge conjugation. Conservation laws. Classifications of elementary particles – hadrons and leptons, baryons and mesons, elementary ideas about quark structure of hadrons – octet and decuplet families. Particle Accelerator and Detector Cyclotron – basic theory, synchrotron, GM counter	18

REFEENCE BOOKS:

- Nuclear Physics – Cottingham and Greenwood (Cambridge UniversityPress).
- Concepts of Nuclear Physcics – R. Cohen (Tata-Mc GrawHill).
- Paramanu o KendrakGathan Parichay – S. N. Ghoshal(WBSBB).
- Atomic and Nuclear Physics – S. N. Ghoshal (S.Chand).
- Nuclear Physics – S. B. Patel (New Age).
- Nuclei and Particles – E. Segre (Benjamin).
- Nuclear Physics: Principles and applications – J.S. Lilley (Willey Eastern).
- Fundamentals in Nuclear Physics: from Nuclear Structure to Cosmology – J. Basdevant, J. Rich and M. Spiro (Springer).
- Particle Physics – Seiden (Persian Education)

PHY 353 MJE: Atomic and Molecular Spectroscopy and Lasers

This course intends to throw light on the phenomenon of the interaction of light with matter in terms of the relationship with the molecular structure. The course will enable students to select molecular spectroscopy methods suitable for solving given scientific problem.

PHY 353 MJ: Atomic and Molecular Spectroscopy and Lasers - 4 Credits	
Atomic Spectroscopy	**No. of lectures**
LS and JJ coupling schemes. Terms for equivalent and non-equivalent electron atom. Spectra of one and two electron systems. Electron spin, spin orbit interaction, fine structure, relativistic correction and radiation correction (Lamb Shift). Electric dipole selection rules. Intensity rules. Alkali type spectra. Zeeman effect. Paschen-Back effect. Stark effect. Hyperfine structure and isotopic shifts. Complex Spectra: Vector model for three or more valence electrons. Inverted terms. Compound doublet. Inner-Shell Excitation and Auto ionization, Line intensities, Transition probabilities, oscillator strength. Forbidden transitions.	15
Molecular Spectroscopy	**No. of lectures**

Rotational spectra of diatomic molecules. Vibrational spectra of diatomic molecules. Rotation- Vibration spectra of diatomic molecules. Classification of electronic states. Electronic spectra of diatomic molecules. Franck-Condon principle. Rotational spectra of linear polyatomic molecules: Coriolis interaction and effect of l-type doubling in linear molecules. Nuclear spin statistical weights and their effect on intensities. Rotational spectra of symmetric (prolate and oblate) molecules. Vibration-rotation spectra of polyatomic molecules: Parallel and perpendicular bands of linear molecules and symmetric top (prolate and oblate) molecules.	15
Spectroscopy (elementary and qualitative)	**No. of lectures**
Experimental techniques in spectroscopy: FTIR Raman, Stoke's antiStoke's.	3
Laser Physics Spectroscopy(elementary and qualitative)	3

REFERENCE BOOKS:

- Eisberg, R. and Resnick, R., Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, II Edition, John Wiley,1985
- Banwell, C.N., Fundamentals of Molecular Spectroscopy, III Edition, Tata-McGraw Hill,1972
- Wilson, J. and Hawkes, J. F. B., Optoelectronics- An Introduction, Prentice Hall,1983

PHY 354 MN: Digital and Analog Electronics

This course is designed for students to know the operation and the structure of switching circuits, use and working of diodes and transistors as a switching circuits, logic families, TTL, ECL, and MOSFET and amplifiers etc

PHY 354 MJ: Digital and Analog Electronics -4 Credits	
Digital Circuits	**No. of lectures**
Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion, AND, OR and NOT Gates (Realization using Diodes and transistors)	4
De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Minterms and	5
Maxterms. Conversion of a Truth Table into an Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.	
Binary Addition. Binary Subtraction using 2's Complement Method). Half Adders and Full Adders and Subtractors, 4-bit binary Adder-Subtractor.	4
Semiconductor Devices and Amplifiers:	**No. of lectures**

Semiconductor Diodes: P and N type semiconductors. Barrier Formation in PN Junction Diode. Qualitative Idea of Current Flow Mechanism in Forward and Reverse Biased Diode. PN junction and its characteristics. Static and Dynamic Resistance. Principle and structure of (1) LEDs, (2) Photodiode, (3) Solar Cell.	5
Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Active, Cutoff & Saturation regions Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line & Q-point. Voltage Divider Bias Circuit for CE Amplifier. h-parameter Equivalent Circuit. Analysis of single-stage CE amplifier using UGC Document on LOCF Physics 233 hybrid Model. Input & output Impedance. Current, Voltage and Power gains. Class A, B & C Amplifiers	12
Operational Amplifiers (Black Box approach):	**No. of lectures**
Characteristics of an Ideal and Practical Op-Amp (IC 741), Open-loop and closed-loop Gain. CMRR, concept of Virtual ground. Applications of Op- Amps: (1) Inverting and non-inverting Amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Zero crossing detector.	6

Sinusoidal Oscillators: Barkhausen's Criterion for Self-sustained Oscillations. Determination of Frequency of RC Oscillator	

REFERENCEBOOKS:

- Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
- Electronic devices & circuits, S. Salivahanan & N.S. Kumar, 2012, Tata Mc- Graw Hill
- Microelectronic Circuits, M.H. Rashid, 2nd Edn., 2011, Cengage Learning.
- Modern Electronic Instrumentation and Measurement Tech., Helfrick and Cooper,1990, PHI Learning
- Digital Principles and Applications, A.P. Malvino, D.P. Leach and Saha, 7th Ed., 2011, Tata McGraw Hill
- Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6th Edn., Oxford University Press.

PHY 391 MJ: Renewable Energy and Energy Harvesting

This course enables the students to outline the principles of energy harvesting systems as well as methods of electro-mechanical conversion, principle of photovoltaic cells and thermoelectric generators. They will be able to describe the physical principles of energy harvesting methods mainly electro-mechanical conversion and simulation modeling of such mechatronic systems.

MN 391 PHY: Renewable Energy and Energy Harvesting **- 2 Credits**	
Fossil fuels and Alternate Sources of energy	**No. of lectures**

Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity	3
Solar energy	**No. of lectures**
Its importance, storage of solar energy, solar pond, no convective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption	3
Ocean Energy, Hydro Energy and Geothermal Energy	**No. of lectures**
Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices. (3 Lectures) Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Bio-mass. (2 Lectures) Geothermal Resources, Geothermal Technologies. Hydropower resources, hydropower technologies, environmental impact of hydro power sources	6
Piezoelectric Energy harvesting	**No. of lectures**
Introduction, Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modeling piezoelectric generators, Piezoelectric Energy harvesting applications, Human power	4
Electromagnetic Energy Harvesting	**No. of lectures**
Electromagnetic Energy Harvesting	2
Linear generators, physics mathematical models, recent applications	2
Environmental issues and Renewable sources of energy, sustainability.	2

REFERENCE BOOKS:

- Non-conventional energy sources - G.D Rai - Khanna Publishers, New Delhi
- Solar energy - M P Agarwal - S Chand and Co. Ltd.
- Solar energy - Suhas P Sukhative Tata McGraw - Hill Publishing Company Ltd.
- Godfrey Boyle, “Renewable Energy, Power for a sustainable future”, 2004,Oxford University Press, in association with The Open University.
- Dr. P Jayakumar, Solar Energy: Resource Assesment Handbook,2009
- J.Balfour, M.Shaw and S. Jarosek, Photo voltaics, Lawrence J Goodrich (USA).
- http://en.wikipedia.org/wiki/Renewable_energy

PHY332 RP- Research Project work/ FP/ OJT- 2 Credits

Combination of experimental and theoretical aspects of a problem. Perform experiment, collect data, analyze with various tools and software. Derive conclusion (positive or negative) from the work and summarize the report in form of dissertation in the VI semester.