UNDERGRADUATE PROGRAMME IN ENVIRONMENTAL SCIENCE

2022

(Based on the NEP-2020, LOCF & CBCS)

In accordance with the Manipur University's Ordinance for Undergraduate Programmes on Science, Arts and Commerce, 2021

OFFICE OF THE PRINCIPAL
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DEPTT OF FORESTRY AND ENVIRONMENTAL SCIENCE

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PREAMBLE

Historically environment and conservation have been an integral part of India's ethical and spiritual values from ancient times. This is evident from the importance given to nature in the Vedic literature and epics the Ramayana and Mahabharata. Buddhism and Jainism have also given great importance to the conservation of natural resources and biodiversity. In more recent times, the value of flora and fauna has been documented by regimes of the Mughals and the British. The exploitation of our resources during British India required the introduction of formal educational processes to document India's biological resources. This tradition continued after independence as nature studies in school and college education.

The world got together to ensure preservation and enhancement of the human environment in Stockholm in 1972. Nations, irrespective of their economic status, have been facing newer environmental challenges of local, regional and global nature. Therefore, human beings needed to continue learning about the environment to appreciate the challenges and to find solutions. India has been quick to respond to the need and carefully added clauses in the Constitution of India to address the environmental concerns. Laws have been enacted as a commitment to the international community and to address Indian national concerns, and institutions like the Pollution Control Boards have been constituted. Consequently, over the years, Environmental Science has developed as an academic discipline and the need to create research base and technical manpower in the areas of Environmental Science has been felt world over.

By the 1970s, it was observed that current patterns of development and our population growth placed enormous impacts on natural resources. The degradation of our environment such as deforestation, pollution, the spread of wasteland etc. led to the need for placing environment education in curricula. The Honorable Supreme Court, in response to MC Mehta's PIL, introduced formal environment education as an infusion into school curricula in different subjects. In 1991, the UGC created a compulsory Core Module Undergraduate Course on Environmental Studies to be implemented in all subjects at the undergraduate level. This is now referred to as 'Ability Enhancement Compulsory Course (AECC)'. During the last few years, several universities have initiated their courses on the environment in response to growing societal and industrial needs. As these provide disparate inputs, it is difficult for job opportunity providers to judge the competence level of job seekers on a single platform. Thus there is a growing felt need for a standardize honours programme on the environment at the bachelor's level.

The undergraduate programme in Environmental Science programme and its LOCF curriculum have been designed to attract young minds to choose a career in broad areas of Environmental Science and applications. This programme has also been envisaged to fill the requirement of technical manpower in various sectors in India and elsewhere.

1. INTRODUCTION

Environmental Science has developed as a discipline of interdisciplinary nature. Therefore, explicit learning outcomes against the courses would provide a direction to the students and teachers to focus effectively on the subject. The recruiters would find it easier to visualize their internal needs and relate them to the available expertise of the graduates seeking jobs in this field. Thus, the learning outcomes based curriculum framework (LOCF) for Undergraduate Programme in Environmental Science has been envisaged to fill the gap that existed between the recruiters and academic institution, besides maintaining the standards of teaching-learning in the competitive world of today. The framework intends to bring in innovation in curriculum design and syllabus development, teaching-learning, and rational assessment of the students.

Since Environmental Science is an interdisciplinary subject, the candidates are expected to acquire skills in natural resource management, pollution control and social issues related to equitable use of resources. Some topics in the Core courses may overlap with a similar Discipline Specific Elective (DSE) courses. However, the DSE courses in greater detail provide with opportunities for hands-on relevant training, exposure visits, skill development and project work. Several courses may be supplemented by creating MOOCs through the e-Pathshala programme of the UGC.

As the environment and its studies are based on current and past scenarios, spatial and temporal aspects should become a part of a students' knowledge domain and acquired skills. This requires the student to have passed through a personal learning adventure into her/hisenvironment and experiential learning, which is the foundation for critical and reflective learning.

The LOCF for Undergraduate Programme in Environmental Science has been prepared as per the structure provided by the UGC, however, the multidisciplinary nature of the subject and the field application of knowledge has been emphasized. Environmental Science is (also) an emerging discipline and so revision and amendments are inevitable, however, any modification must keep the spirit of CBCS and LOCF intact.

2. LEARNING OUTCOMES BASED APPROACH TO CURRICULUM PLANNING

Domain knowledge, academic outlook, critical approach and thinking, ethical attitude, professional aptitude, adaptability, self-learning, problem solving ability, teamwork performances, and employability are the basis of the learning outcomes based curriculum. The learning outcomes are the ingredients based on which the graduate attributes, qualification descriptors, programme learning outcomes are determined. This also facilitates in curriculum planning and development as well as in the delivery and review of academic programmes.

2.1. Nature and extent of Undergraduate Programme in Environmental Science

Undergraduate Programme in Environmental Science is a natural science programme. This programme will make graduates ready to take up higher studies in Environmental Science and to take up careers in the fields of environmental research and learning. The environmental commitments of the society have grown since Stockholm 1972 and, therefore, all organisations have the immediate need of technical manpower and the knowhow to handle the environmental needs of different sorts of today of the nature of scientific, technological, remedial and socioeconomic types. This programme would deal with the topics that will cover issues from all attributes of the environment; issues from physical environment to socioeconomic and cultural environment. This learning outcomes based curriculum for this programme would have definite goals to be achieved to keep the students, teachers and the offering institutions stay focused on the primary objectives of the programme. The detailed programme learning outcomes are listed in the later sections.

This is a job oriented programme and relevant to the current needs of the society. The extent (scope, depth, and outcomes) of Undergraduate Programme in Environment Science programme has taken into account the extent of the knowledge provided at school level in 10th, 11th and 12th standard according to syllabi of NCERT and state boards. It has been designed to bridge the gap between the school level and M.Sc. programme on environment and its management offered by various universities. This is essential because of the interdisciplinary nature of the subject. More so, there is a current trend to look at the environment through a trans-disciplinary approach which is relevant by the nature of the subject and the socio-economic fabric of India.

2.2. Aim of Undergraduate Programme in Environmental Science

The aims of the Undergraduate Programme in Environmental Science are to:

- Provide students with the scope to develop knowledge base covering all attributes of the environment and enable them to attain scientific/technological capabilities to find answers to the fundamental questions before the society with regards to human action and environmental effects with due diligence.
- Enhance the ability to apply this knowledge and proficiency to find solutions relating to environmental concerns of varied dimensions of today.
- Provide with a direction and technical capability to carry on lifelong learning and show teamwork and collaborative endeavour, and decision making.
- Improve the employability of the graduates including the enhancement of self- employment and entrepreneurial aptitude, and fill the technical resource gap especially in the Indian context.
- Help graduates appreciate environmental needs to frame policy guidelines.
- Motivate graduates to appreciate that they are an integral stakeholder in the environmental management of India irrespective of their future jobs or working environments in accordance of the provisions vide Article 48A (Directive Principles of State Policy) and Article 51A (g) (Fundamental Duties) of the Constitution of India.
- Help graduates to understand the concerns related to Sustainable Development Goals (SDGs) and the Indian obligations.

3. QUALIFICATION DESCRIPTORS FOR UNDERGRADUATE PROGRAMME IN ENVIRONMENTAL SCIENCE

The qualification descriptors for the Undergraduate Programme in programme in Environmental Science shall be five learning attributes such as disciplined knowledge & understanding; skills & techniques; national and global competencies; communication; and application. The key qualification descriptor for Environmental Honours shall be the strong foothold of the basic scientific theories and principles as well as critical thinking and decision making. The major expected learning outcomes of the Undergraduate Programme in Environmental Science should include the following:

3.1 Knowledge & Understanding

- Demonstrate extensive and systematic acquaintance of the disciplinary foundation in the various areas of Environmental Science.
- Insightfully address the contemporary research and development at both national and international arena.
- Understand and engage in the field of Environmental Sciences and its allied areas.

3.2 Skills & Techniques

- *Show* the ability to apply scientific knowledge & experimental skills in a critical and organized manner for evaluation and elucidation of complex environmental problems and issues related to terrestrial ecosystems; physical environment; air, water, and soil.
- *Contamination*; human health hazards; biodiversity loss; food security and agricultural issues; solid waste management; and other specialized areas of electronics.
- *Demonstrate* the ability to identify the role of the scientific knowledge, experimental skills, scientific methods & tool in dealing with real-life case-specific issues and formulate sustainable solutions.
- *Exhibit* efficiency to model, simulates, and assesses the regional and global phenomenon and systems with both primary and secondary data sources.
- *Demonstrate* the ability to facilitate technocrats and manufacturers to design and develop eco-friendly products and processes towards accomplishment of the sustainable development goals.

3.3 Competence

- *Communicate* heterogeneous audience through his or her information, knowledge, and arguments effectively and professionally with write-ups and presentations in both national and international perspectives.
- *Ability* to work as a proactive and supportive member in a team through substantial contributions towards effective planning, management, and implementations of projects and/or tasks.
- *Exhibit* capability to think and execute independent research ventures/projects, interpret changes and fluctuations in the natural environment, predict or estimate probable environmental consequences of any process, evaluate research outcomes, and report in a conclusive and convincing manner.
- *Capability t*o identify his or her strengths and limitations; develop an attitude to learn more; inculcate a lifelong learning practice; and grow as pragmatic knowledge seekers as well as knowledge creators.

4. GRADUATES ATTRIBUTES

Graduates Attributes (GAs) are composed of independently measurable outcomes that signify the capabilities and potentials of the graduate to attain accomplishment and perform in adequate manner at appropriate situations. The Graduate Attributes of Undergraduate Programme in Environmental Science are given as below:

GA1. Erudition of acquaintance: Gain in-depth knowledge and understandings of each discipline or professional area across boundaries of nations with an aptitude to identify, access, analyze and synthesize existing and new knowledge, and integrate them for the enrichment of knowledge.

GA2. Analytical Thinking: Critically to address multifaceted scientific issues and environmental phenomenon; pertain independent decision for synchronizing information to formulate innovative and intellectual advances towards focused research over wider theoretical and practical domains.

GA3. Problem Solving: Address and solve scientific vis-a-vis environmental problems via rational and original thinking; keep updates of different solution avenues and select appropriate options considering public health, cultural, and societal factors.

GA4. Application of modern tools: Select, learn and apply appropriate techniques, resources, sophisticated instruments, models for explaining different environmental consequences and mitigation activities with a thorough understanding of drawbacks.

GA5. Mutual and Multidisciplinary competence: Develop sound knowledge and perception about group dynamics, recognize role of individuals in a group, take initiatives and leadership in collaborative-multidisciplinary and trans-disciplinary scientific research, demonstrate a capacity for self-management and teamwork, timely decision-making through openness and flexibility, constructive arguments and rational analysis for achieving common goals and objectives; motivate group members to address

environmental issues with a scientific outlook and mitigation approach.

GA6. Communication skill: Communicate scientific/technological knowhow and new learning to the scientific community and the society at large with strong conviction and confidence so that humanity benefit from the knowledge and technological development. This can be achieved through sound technical proficiency of graphics, software, writing skill, in-depth subject specifics knowledge, by maintaining appropriate standards, by the ability to render as well as receive comprehensible instructions.

GA7. Life long Learning: Distinguish the importance and possess the ability to prepare and engage in the life long learning process; also have the ability to transfer the acquired skills in other domains of science; which can be achieved through enthusiasm and commitment to improving knowledge and competence in a continuous manner.

GA8. Ethical values and Social Responsibility: Attain strong academic integrity, professional code of conduct, ethics of experimental research and scientific writings, contemplation of the impact of research findings on conventional practices, and a clear sense of responsibility towards societal needs and reaching the targets for attaining inclusive and sustainable development.

GA9. Futuristic attitude: Ability to recognize and address current environmental scenarios, scientific and technological progress, lifestyle change, and biophysical evolutions with a futuristic view; practicing intuitiveness and interest towards scientific prediction via application of basic knowledge of science especially with regard to India's SDGs in terms of economic welfare, social equity and proactive long-term environment management.

5. PROGRAM LEARNING OUTCOMES OF UNDERGRADUATE PROGRAMME IN ENVIRONMENTAL SCIENCE

The following program outcomes have been identified for Undergraduate Programme in Environmental Science

PLO1	Ability to recognize the need for learning the topic and develop foundational knowledge on the topic.
PLO2	Ability to develop critical thinking and problem solving skills to solve interdisciplinary issues related to the topic.
PLO3	Ability to understand the relationships between natural and man-made systems.
PLO4	Ability to apply statistical methods, ICT and innovative techniques in classroom, field and laboratory to analyze scientific data.
PLO5	Ability to develop lifelong learning and professional skills.
PLO6	Ability to design and execute a scientific project, write scientific reports, develop research and communication skills.
PLO7	Ability to spread awareness about the environment around us, sustainable development and conduct outreach activities.
PLO8	Ability to gain empirical knowledge on the topic and contribute in decision making processes.

5.1 Mapping of course with program outcomes (PLOs)

Sem	Course title	PLO1:Ability to recognize then feed for learning the topic and develop foundational knowledge on the topic	PLO1:Abilitytodevelopcriticalthinking and problem solving skills to solve inter disciplinary issue related to the topic	PLO1:Ability to understand the relationships between natural and man-made systems	PLO1:Ability to apply statistical methods, ICT and innovative techniques in classroom, field and laboratory to analyze scientific data	PLO1:Ability to develop lifelong learning and professional skills	PLO1:Ability to design and execute a scientific project, written Scientific reports, develop research and	PLO1:Ability to spread awareness about the environment around us, sustainable development and conduct outreach activities	PLO1:Ability to gain empirical knowledge on the topic and contribute in decision making processes
1st	EN501: Introduction to the Environment	X	X	X			X	X	X
1st	EN502: Natural Resource Management & Sustainable Development	X	X	X		X	X	X	X
2nd	EN503: Introduction to the Biological Environment	X	X	X		X	X		X
2nd	EN504: Introduction to the Physical Environment	X	X	X			X		X
3rd	EN601: Fundamentals of Ecology	X	X	X			X	X	X
3rd	EN602: Biodiversity and Conservation	X	X	X			X	X	X
3rd	EN603: Water Resources	X	X	X			X		X
4th	EN604: Solid Waste Management	X	X			X	X	X	X
4th	EN605: Environmental Chemistry	X	X	X	X		X		X
4th	EN606:Basics of Environmental Statistics & Computer Application				X	X	X		
5th	EN701:Environmental Pollution and Human Health	X	X	X			X	X	X
5th	EN702: Environmental Instrumentation				X	X			
6th	EN703: Environmental Legislation and Policy	X	X	X		X		X	X
6th	EN704: Atmospheric Processes	X	X			X	X	X	X
7th	EN801: Wildlife Conservation and Management	X	X	X			X	X	X
7th	EN802: Introduction to Climate Change	X	X			X	X	X	X
8th	EN803: Energy and Environment	X	X	X		X	X	X	X
8th	EN804: Natural Hazards and Disaster Management	X	X	X		X	X	X	X
5-6th	EN711: Environmental Economics	X	X			X	X	X	X
5-6th	EN712: Land and Soil Conservation and Management	X	X	X		X	X	X	X
5-6th	EN713: Soil Remediation and Restoration	X	X	X		X	X	X	X
5-6th	EN714: Environmental Modelling	X	X		X	X	X	X	X
7-8th	EN811: Water Treatment Technology	X	X	X		X	X	X	X
7-8th	EN812: Air Pollution Monitoring and Control	X	X	X		X	X	X	X
7-8th	EN813: Environmental Biotechnology	X	X	X	X		X		X
7-8th	EN814: Industrial Health and Safety	X	X	X	X		X		X
7-8th	EN815: Project/Dissertation†	X	X	X	X	X	X	X	X

6. PROGRAMME STRUCTURE OF UNDERGRADUATE PROGRAMME IN ENVIRONMENTAL SCIENCE

TOTAL CREDITS: 200 CREDITS

Structure of Undergraduate Programme in Environmental Science

	No of courses	Credits per course	Total Credits
I. Core courses	18	6	108
II. Elective courses : Discipline Specific Courses (DSE)** (Optional *Dissertation or project* work in place of one DSE paper of 6 Credits in the 8th Sem)	4	6	24
III. Ability Enhancement Courses (AECC)English/ Hindi/MIL/communication	2	4	8
IV. Skill Enhancement Courses (SEC)**	2	4	8
V. General Elective Courses (GEC)	6	6	36
VI. Value Addition Courses (VAC)	8	2	16
		Total:	**200**

6.1. Course structure

SEMESTER I

Course type	Course title	Credits
Core	Core 1:Introduction to the Environment	6
	Core 2: Natural Resource Management and Sustainable Development	6
SEC	SEC-1	4
AECC	AECC-1 : English	4
VAC	VAC-1	2
VAC	VAC-2	2
	Total:	24

SEMESTER II

Course type	Course title	**Credits**
Core	Core 3: Introduction to the Biological Environment	6
	Core 4: Introduction to the Physical Environment	6
SEC	SEC-2	4
AECC	AECC-2: Environmental Sc.	4
VAC	VAC-3	2
VAC	VAC-4	2
	Total:	**24**
Exit option with Bachelor's Certificate in Environmental Science on completion of courses equal to a minimum of 46 credits		

SEMESTER III

Course type	Course title	Credits
Core	Core 5: Fundamentals of Ecology	6
	Core 6: Biodiversity and Conservation	6
	Core 7: Water Resources	6
GEC	GEC-1	6
VAC	VAC-5	2
	Total:	**26**

SEMESTER IV

Course type	Course title	**Credits**
Core	Core 8: Solid Waste Management	6
	Core 9: Environmental Chemistry	6
	Core 10: Basics of Environmental Statistics and Computer Application	6
GEC	GEC-2	6
VAC	VAC-6	2
	Total:	**26**
Exit option with Bachelor's Diploma in Environmental Science on completion of courses equal to a minimum of 96 credits		

SEMESTER V

Course type	Course title	**Credits**
Core	Core 11: Environmental Pollution and Human Health	6
	Core 12: Environmental Instrumentation	6
DSE	DSE-1	6
GEC	GEC-3	6
VAC	VAC-7	2
	Total:	**26**

SEMESTER VI

Course type	Course title	**Credits**
Core	Core 13: Environmental legislation and policy	6
	Core 14: Atmospheric processes	6
DSE	DSE-2	6
GEC	GEC-4	6
VAC	VAC-8	2
	Total:	**26**
Exit option with Bachelor's Degree in Environmental Science on completion of courses equal to a minimum of 140 credits		

SEMESTER VII

Course type	Course title	**Credits**
Core	Core 15: Wildlife Conservation and Management	6
	Core 16: Introduction to Climate Change	6
DSE	DSE-3	6
GEC	GEC-5	6
	Total:	**24**

SEMESTER VIII

Course type	Course title	**Credits**
Core	Core 17: Energy and Environment	6
	Core 18: Natural Hazards and Disaster Management	6
DSE	DSE-4 (or Dissertation)	6
GEC	GEC-6	6
	Total:	**24**
Exit option with Bachelor's Degree with Honours Environmental Science on completion of courses equal to a minimum of 182 credits		

The undergraduate academic programme governed by this Ordinance shall be of four years duration with multiple exit options within this period with appropriate certifications namely,

(a) Bachelor's Certificate : The Bachelor's Certificate in Environmental Science is obtainable after year (two semesters) of study. A Bachelor's Certificate in a discipline may be awarded if student studies 4 core papers in that discipline, 2 Ability Enhancement Compulsory Courses (AECC), 2 Skill Enhancement Courses (SEC) and minimum 3 Value Addition Courses (VAC), with the completion of courses equal to a minimum of 46 Credits.

(b) Bachelor's Diploma: The Bachelor's Diploma in Environmental Science is obtainable after 2 years (four semesters) of study. A Bachelor's Diploma in a discipline may be awarded if a student studies 10 core papers in that discipline, 2 Ability Enhancement Compulsory Courses (AECC), 2 Skill Enhancement Courses (SEC), minimum 4 Value Addition Courses (VAC) and 2 Generic Elective courses (GEC), with the completion of courses equal to a minimum of 96 Credits.

(c) Bachelor's Degree: The Bachelor's Degree in Environmental Science is obtainable after 3 years (six semesters) of study. A Bachelor's degree (i.e., B.Sc) in a discipline degree may be awarded if a student studies 14 core papers in that discipline, 2 Ability Enhancement Compulsory Courses (AECC), 2 Skill Enhancement Courses (SEC), minimum 5 Value Addition Courses (VAC), 2 Discipline Specific Elective (DSE) courses and minimum 3 Generic Elective (GE) courses, with the completion of courses equal to a minimum of 140 Credits.

(d) Bachelor's Degree: The Bachelor's Degree with Honours in Environmental Science is obtainable after 4 years (eight semesters) of study. A Bachelor's degree with Honours (B.Sc. (Honours)) in a discipline may be awarded if a student studies 18 core papers in that discipline, 2 Ability Enhancement Compulsory Courses (AECC), 2 Skill Enhancement Courses (SEC), minimum 5 Value Addition

Courses (VAC), 4 Discipline Specific Elective (DSE) and minimum 4 Generic Elective courses (GEC), with the completion of courses equal to a minimum of 182 Credits.

6.2. Academic Year: Two consecutive (one odd one even) semesters constitute one academic year.

6.3. Semester: Each semester will consist of 15-16 weeks of academic work equivalent to 90 actual Teaching days. In a bi-semester system, an academic year consists of two semesters. The odd semesters may be scheduled from June/July to November/ December, and even semester from November/ December to April/May.

6.4. Programme: A programme, herei nafter, shall mean an academic programme leading to award of a degree, diploma or certificate. It comprises of a fixed set of core (compulsory) Courses and some choice based (optional) Courses with a minimum Credit requirement.

6.5. Course: A course, usually referred to as 'paper', is a component of a Programme, comprising one or a combination of some academic forms of instructions such as lectures, tutorials, laboratory work, field work, outreach activities, project work, vocational training, viva, seminars, term papers, assignments, presentations, self-study etc. or a combination of some of these. All courses should define learning objectives and students learning outcomes. Each course is to be identified by a unique course code and course title.

6.6. Credit: Credit defines the quantum of work-load for a course. Generally, one hour of theory or one hour of tutorial or two hours of laboratory work, per week for a duration of a semester result in the award of one credit. Credits for internship shall be one credit per one week of internship, subject to a maximum of six credits.

6.7. Grade Point: It is a numerical weight allotted to each letter grade on a 10-point.

6.8. Letter Grade: It is an index of the performance of students in a course. Grades scale. Scale are denoted by letters O, A+, A, B+, B, C, P, F and Ab.

6.9. Credit Point: It is the product of grade point and number of credits for a course.

6.10. Semester Grade Point Average (SGPA): It is a measure of performance of work done in a semester. It is ratio of total credit points secured by a student in various courses registered in a semester to the total course credits taken during that semester. It shall be expressed up to two decimal places.

6.11. Cumulative Grade Point Average (CGPA): It is a measure of overall cumulative performance of a student over all semesters. The CGPA is the ratio of total credit points secured by a student in various courses in all semesters to the sum of the total credits of all courses in all the semesters. It is expressed up to two decimal places.

6.12. Transcript or Grade Card or Certificate: Based on the grades earned, a grade certificate shall be issued to all the registered students after every semester. The grade certificate will display the course details (code, title, number of credits, grade secured) along with SGPA of that semester and CGPA earned till that semester.

7. MULTIPLE ENTRY AND EXIT OPTIONS

The entry and exit options for students, who enter the undergraduate programme, shall be as follows:

1ST YEAR

Entry 1: The entry requirement for Bachelor's certificate (Level 5) programme is Secondary School Leaving Certificate obtained after the successful completion of Grade 12. A programme of study leading to entry into the first year of the Bachelor's degree is open to those who have met the entrance requirements, including specified levels of attainment at the secondary level of education specified in the programme admission regulations. Admission to the Bachelor's degree programme of study is based on the evaluation of documentary evidence (including the academic record) of the applicant's ability to undertake and complete a Bachelor's degree programme.

Exit 1: Bachelor's certificate will be awarded when a student exits at the end of 1st year (Level 5). A Bachelor's certificate requires completion of courses equal to a minimum of 46 Credits at Level 5.

2ND YEAR

Entry 2. The entry requirement for Bachelor's diploma (Level 6) is a Bachelor's certificate obtained after completing the first year (two semesters) of the undergraduate programme. A programme of study leading to the second year of the Bachelor's degree is open to those who have met the entrance requirements, including specified levels of attainment, in the programme admission regulations. Admission to a programme of study is based on the evaluation of documentary evidence (including the academic record) of the applicant's ability to undertake and complete a Bachelor's degree programme.

Exit 2: At the end of the 2nd year (Level 6), if a student exits, a Bachelor's diploma shall be awarded. A Bachelor's Diploma requires completion of courses.

3RD YEAR.

Entry 3. The entry requirement for an undergraduate programme is a diploma obtained after completing two years (four semesters) of the undergraduate programme. A programme of study leading to the Bachelor's degree is open to those who have met the entrance requirements, including specified levels of attainment, in the programme admission regulations. Admission to a programme of study is based on the evaluation of documentary evidence (including the academic record) of the applicant's ability to undertake and complete a degree programme.

Exit 3: On successful completion of three years, the Bachelor's degree shall be awarded. A Bachelor's degree requires completion of courses equal to a minimum of 140 Credits from Level 5 to Level 7.

4TH YEAR

Entry 4. An individual seeking admission to a Bachelor's degree (Honours) (Level8) in a discipline would normally have completed all requirements of the relevant three-year bachelor degree (Level 7) in that discipline. After completing the requirements of a three-year Bachelor's degree, candidates who meet a **minimum CGPA of 7.5** shall be allowed to continue studies in the fourth year of the undergraduate programme to pursue and complete the Bachelor's degree with Honours in the discipline.

Exit 4: On the successful completion of the fourth year, a student shall be awarded a Bachelor's degree with Honours in the concerned discipline. A Bachelor's degree with Honours requires completion of courses equal to a minimum of 182 Credits from Level 5 to Level 8.

8. COURSES OF UNDERGRADUATE PROGRAMMES

The undergraduate programmes shall contain the following course components:

8.1 Core Course: This is a course which is to be compulsorily studied by a student as a core requirement to complete the requirement of a programme in Environmental Science. Each of the Core Courses shall contain two components: Theory and Practical/Tutorial. Theory Paper having Practical shall carry 4 Credits so that Practical carries 2 Credits. Theory Paper having Tutorial shall carry 5 Credits so that Tutorial carries 1 Credits.

8.2 Elective Course**:** Generally, an elective course is a course which can be chosen from a pool of courses which may be very specific or specialized or advanced or supportive to the discipline/ subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate's proficiency/skill.

An elective course may be three types:

(a) Discipline Specific Elective (DSE) Course: Elective courses offered by the main discipline/subject of study are referred to as Discipline Specific Elective Courses. This course is to advance knowledge and skill in the core domain. Each of the DSE courses shall contain two components: Theory and Practical/Tutorial. Theory Paper having Practical shall carry 4 Credits so that Practical carries 2 Credits. Theory Paper having Tutorial shall carry 5 Credits so that Tutorial carries 1 Credit.

(b) Dissertation/Project/Internship: An elective course designed to acquire special/advanced knowledge is termed as dissertation/project. This is considered as a special course involving application of knowledge in solving/ analyzing/ exploring a real life situation/ difficult problem. Dissertation/Project Work/Internship is optional and it may be offered in lieu of a discipline specific elective paper in 8th Semester.

(c) Generic Elective Course (GEC): An elective course chosen generally from an unrelated discipline/subject, with an intention to seek a wide exposure is called a Generic Elective. A core course offered in a discipline/subject may be treated as an elective by other

discipline/subject and vice versa and such electives may also be referred to as Generic Elective. Each of the GEC Courses shall contain two components: Theory and Practical/Tutorial. Theory Paper having Practical shall carry 4 Credits so that Practical carries 2 Credits. Theory Paper having Tutorial shall carry 5Credits so that Tutorial carries 1 Credit**.**

8.3 Ability Enhancement Course: The Ability Enhancement Course may be of two kinds: Ability Enhancement Compulsory Courses (AECC) and Skill Enhancement Courses (SEC). AECC courses are the courses based upon the content that leads to Knowledge enhancement: (i) Environmental Science and (i) English/MIL Communication. These are mandatory for all disciplines. SEC courses are value-based and/or skill-based and are aimed at providing hands-on-training, competencies, skills, etc. These may be chosen from a pool of courses designed to provide value-based and/or skill-based knowledge. Each of the AECC and SEC courses shall carry Credits.

8.4 Value Addition Courses (VAC): These are courses that will help develop all capacities of human beings-intellectual, aesthetic, social, physical, emotional, and moral in an integrated manner. It includes subjects like Yoga, Sports, Health Care, NCC, NSS, Ethics, Culture etc. VAC courses may be chosen from a pool of courses. Each VAC course shall carry Credits.

9. LIST OF COURSES

A. Core courses

Sem	Course title	Lecture (L)	Tutorial (T)	Practical (P)*	Contact Hour	Credits
1st	EN501: Introduction to the Environment	4	0	2	6	6
1st	EN502: Natural Resource Management & Sustainable Development	5	1	0	6	6
2nd	EN503: Introduction to the Biological Environment	4	0	2	6	6
2nd	EN504: Introduction to the Physical Environment	4	0	2	6	6
3rd	EN601: Fundamentals of Ecology	5	1	0	6	6
3rd	EN602: Biodiversity and Conservation	4	0	2	6	6
3rd	EN603: Water Resources	4	0	2	6	6
4th	EN604: Solid Waste Management	4	0	2	6	6
4th	EN605: Environmental Chemistry	4	0	2	6	6
4th	EN606:Basics of Environmental Statistics & Computer Application	4	0	2	6	6
5th	EN701:Environmental Pollution and Human Health	4	0	2	6	6
5th	EN702: Environmental Instrumentation	4	0	2	6	6
6th	EN703: Environmental Legislation and Policy	5	1	0	6	6
6th	EN704: Atmospheric Processes	4	0	2	6	6
7th	EN801: Wildlife Conservation and Management	4	0	2	6	6
7th	EN802: Introduction to Climate Change	5	1	0	6	6
8th	EN803: Energy and Environment	5	1	0	6	6
8th	EN804: Natural Hazards and Disaster Management	4	0	2	6	6

B. Discipline Specific Courses (DSE)

Sem	Course title	Lecture (L)	Tutorial (T)	Practical (P)*	Contact Hour	Credits
5th	EN711: Environmental Economics	5	1	0	6	6
5th	EN712: Land and Soil Conservation and Management	4	0	2	6	6
6th	EN713: Soil Remediation and Restoration	4	0	2	6	6
6th	EN714: Environmental Modelling	5	1	0	6	6
7th	EN811: Water Treatment Technology	4	0	2	6	6
7th	EN812: Air Pollution Monitoring and Control	4	0	2	6	6
8th	EN813: Environmental Biotechnology	4	0	2	6	6
8th	EN814: Industrial Health and Safety	5	1	0	6	6
8th	EN815: Project/Dissertation†	0	0	8	16	6
†Optional: May be offered in lieu of a DSE course						

C. Skill Enhancement Courses (SEC)

Sem	Course title	Lecture (L)	Tutorial (T)	Practical (P)*	Contact Hour	Credits
1st	EN521: Remote Sensing and Geographic Information System & Modelling	4	0	0	4	4
2nd	EN522: Environmental Impact Assessment (EIA)	4	0	0	4	4

D. General Elective Courses (GEC) (students from other disciplines can opt)

Sem	Course title	Lecture (L)	Tutorial (T)	Practical (P)*	Contact Hour	Credits
3rd	EN631: Environmental Awareness	5	1	0	6	6
4th	EN632: Green Technologies	5	1	0	6	6
5th	EN731: Environment and Society	5	1	0	6	6
6th	EN732: Fundamentals of Ecotourism	5	1	0	6	6
7th	EN831: Folk Culture and Traditional Communities of India	5	1	0	6	6
8th	EN832: Environmental Education	5	1	0	6	6

Note:

- *The core courses are mandatory courses listed as 'A' category.*
- *One paper per semester should be opted from the courses listed in 'B' category*
- *Institutes may offer more courses for C and D category of courses without compromising the philosophy of LOCF.*
- *The B, C and D category of courses may not necessarily be from the parent department/college as they are courses of CBCS nature.*

10. DETAILED SYLLABUS (CORE COURSES)

EN501: INTRODUCTION TO THE ENVIRONMENT

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Knowledge of the environment and the role of human beings in shaping the environment
CO2: Understand various components of the environment and interfaces.
CO3: Critically appreciate the environmental concerns of today.

Course Content:

- Environment – Definition and the components – the physical components, socio-economic and cultural components.
- Natural resources – definition and types, resource use and depletion.
- Atmosphere – structure and composition, physicochemical role of the atmosphere.
- Rocks and minerals - the rock cycle, biogeochemical cycles, soil- structure and types.
- Water resources, water bodies and water use, issues with water and conservation.
- Ecosystems – concepts and structure, concepts of biomes, biodiversity.
- Urban environment and issues –waste generation and management, vehicular traffic, air and water pollution, urban heat island, Concept of smart cities, sustainable cities.
- Environmental issues –Concepts of pollution of air, water, and land, urbanization and solid wastes, biodiversity loss, land degradation and desertification, biodiversity loss, ozone layer depletion, climate change.
- Environmental concerns – historical development of environmentalism and conservation on Indian perspective.

Practical:

- ✓ Assessment of ecosystem services provided by the region.
- ✓ Case studies on natural resources exploitation.
- ✓ Basic methods of air, soil and water sampling.
- ✓ Measurement of species diversity (calculation of diversity indices from data collected on plant species from the field).
- ✓ Environment and social impact assessment.
- ✓ Case studies on environmental movements of the region.
- ✓ Field visit and reporting: biodiversity from different habitats; major environmental issues of the region; urban habitat loss; water resources related problem etc.

Recommended Books:

- Cunningham W.P., Cunningham M.A., Saigo B.W., Environmental Science: A global concern, McGrawHill 2003.
- Cunningham W.P., Cunningham M.A, Principles of Environmental Science: Seventh Edition, McGrawHill 2014.
- Rogers P.P., Jalal, K.F., Boyd J.A., An introduction to sustainable development, Earthscan.
- Roosa S.A., Sustainable Development Handbook, CRC Press 2008.
- Atkinson G., Dietz S., Neumayer E., Agarwala M,Handbook of Sustainable Development, Edward Elger, 2014.
- Robbins P., Hintz J., Moore S.A., Environment and Society: A critical introduction,Wiley Blackwel 2014.

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EN502: NATURAL RESOURCE MANAGEMENT AND SUSTAINABLE DEVELOPMENT

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Appreciate attributes of natural resource use and management.
CO2: Understand the complexity of natural resource and issues, and sustainability.
CO3: Apply theories and methods with interdisciplinary approach towards natural resource management.
CO4: Critically examine the gap in the resource availability, use, and conservation.
CO5: Appreciate ideas of sustainable development and application.
CO6: Critically examine the interlink between development and the environment.

Course Content:

- Natural resource - Introduction to earth's natural resources, Occurrence, formation and distribution. Types of natural resources - Renewable and non-renewable resources, Values: economic, societal. Environmental, spiritual, optional and aesthetic values.
- Land resources: forest land, agricultural land, grassland, semi-arid, desert, overutilization and land degradation.
- Forest resources: Major forest types and their characteristics, distribution, utilization of forest resources, issues related to resources harvesting, utilization and degradation.
- Water resources: Fresh and marine water; surface water and ground water, wetlands, rivers, lakes, mangroves, overexploitation, sustainable harnessing of water, rain water harvesting.
- Energy resources: Fossil fuels, nuclear fuels and hydroelectric energy, alternative source of energy (wind, solar).
- Food resources: Food security, food problems, agriculture and effects of modern agriculture.
- Mineral resources: metallic and non-metallic, utilization, and environmental effects.
- Resources extraction, processing and utilization, Mining and its consequences and affects .
- Chain of processes from ore to manufactured object – Life Cycle Assessment (LCA).
- Use to reuse and recycling –Several newer aspects have been suggested for resource use management7R's (Recycle, Refuse, Reduce, Reuse, Repair, Recover, Regift).
- Conservation and management of natural resources, Waste matter: a new source of wealth.
- Humans and conservation, Conservation and protection Sustainable use of natural resources.
- Natural resource management Approaches-Community based natural resource management (CBNRM), Integrated natural resource management (INRM), Natural resources governance and policy.
- Sustainable development - Definition and concept, Determinants of sustainable development, Indicators of sustainable development, Sustainable society, societal prerequisites of sustainable development, International cooperation, Sustainable development goals. Millennium development goals.

Recommended Books:

- Klee G.A., Conservation of Natural Resources. Prentice Hall College Div., 1991.
- Rai G. D., Non-conventional Energy sources. Khanna Publishers, New Delhi.
- Lynch D.R., Sustainable Natural Resource Management: For Scientists and Engineers.

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EN503: INTRODUCTION TO THE BIOLOGICAL ENVIRONMENT

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Understand the biosphere and biotic community.
CO2: Appreciate physiology of plants and animals, and relation with environment.
CO3: Appreciate the Climatic factors, stress and physiology.
CO4: Critically examine the impact of human action on the biological environment.

Course Content:

- Biosphere: Interactions of living species and their changes with the present environmental modifications.
- Understanding Bio complexity: Problems faced by living organisms residing at different habitats and their way of interactions with the environment, India's common flora and fauna. Strategies adopted by plants, animals, fungi, bacteria and archaea to cope with their habitat.
- Animal behaviour and Physiology: Understanding how animals behave and adapt to external environments. Environmental change that favours or dis favours behaviours and physiologies of animals.
- Plant Physiology and Ecophysiology: Key concepts on how plants capture energy and transform it to the ecosystems. The productivity of plants and plants in the field (ecophysiology); their influence on water, carbon, nutrient and energy cycles is central to the functioning of landscapes. Long-distance transport in the phloem; uptake, movement and control of water fluxes in the soil-plant-atmosphere continuum; landscape carbon and water budgets; behavior and physiology of stomata; ion uptake by plant roots; comparative ecophysiology of plants in contrasting environments; the ecophysiology of global forest mortality in response to drought; and the physiology of plants exposed to stress.

Practical:

- ✓ Basic understanding on plant and animal physiology- Growth, development and metabolism: Measuring growth parameters- plants and animals; Biological Imaging and photography; Influence of Acid rain on ecosystem- plants, microbes and aquatic ecosystem; Responses of plant to environment- light, nutrient, CO2.
- ✓ Field visit and reporting: Recording bio-complexity at field level (Relationships within plants, animals and between plants and animals in the ecosystem.

Recommended Books:

- Bhatia A. L., Text book of Environmental Biology, I K International Publishing House (March 27, 2010).
- Saradhi P.P., Biophysical processes in living systems, Oxford & IBH Publishing, 2008.
- Krishnamurthy K.V., An Advanced Text Book on Biodiversity- Principle and Practices, Oxford & IBH Publishing., 2004
- Hock B. and Elstner E. F. F., (eds). Plant Toxicology, Fourth Editon, CRC Press., 2004.
- Ladd P. C., (Ed.) Comparative Animal Physiology, fourth edition, WileyLiss, New York, 1991.
- Calver M., et al (Eds) , Environmental Biology, Cambridge University Press.

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EN504: INTRODUCTION TO THE PHYSICAL ENVIRONMENT

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Should be able to describe the composition and vertical structure of atmosphere.
CO2: Should have understanding of the clear distinction between adiabatic lapse rate and the environmental lapse rate and be able to work out temperatures at higher altitudes based on the lapse rate.
CO3: Should have an understanding of how aerosols impact climate through processes of scattering and absorption of radiations.
CO4: Should be able to describe types of clouds and their structure.
CO5: Should know how geostrophic winds and cyclones are caused in the earth atmospheric system.
CO6: Should be able to appreciate the impact of human activity on the energy balance in the earth atmospheric system.

Course Content:

- Forces of nature, states of matter-solid, liquid and gas. Structure of earth, origin and composition of atmosphere, atmospheric mass, gaseous constituents, trace gases, vertical profile of atmosphere, scale height, thermodynamic properties of atmosphere, gas laws, first and second laws of thermodynamics, isothermal and adiabatic processes, latent heat, sensible heat, virtual temperature, dew point, vapour pressure, saturated vapour pressure, RH, Hydrostatic equation, lapse rates- adiabatic and environmental, mixing height, atmospheric stability classes. Weather and climate.
- Atmospheric aerosols, types and examples, inorganic and organic aerosols, mass transfer, diffusion and transport, particle impaction, sedimentation velocity, relaxation time, stopping distance.
- Transfer of heat, conduction, convection, radiative transfer, radiation laws, solar and terrestrial radiations, Stefan Boltzman law, Wien's law and Planck's law, irradiance, absorption, transmission, reflection, emission and scattering of radiations, Rayleigh and Mie scattering, diffraction. Role of aerosols in climate.
- Clouds microphysical processes, nucleation of water vapour and condensation, structure and types of clouds.
- Atmospheric dynamics, steady and non-steady motion, Geostrophic winds, cyclones, hurricanes and thunderstorms. General circulation, global energy balance, global atmospheric change, simple global temperature models.
- Water budget of the earth atmospheric system, soil resources.

Practical:

- ✓ Determination of meteorological parameters- Atmospheric pressure, Relative Humidity, Wind Speed, Wind direction, construction of wind rose and analysis of meteorological data.
- ✓ Determination of Rainfall using rain gauges.
- ✓ Insolation and light intensity (Lux meter).
- ✓ Field visit: Visit to a national laboratory to see sophisticated instrumentation facilities. Demonstrations for the students may be organized on request.

Recommended Books:

- Wallace J. M. and Hobbs P.V., Atmospheric science, (Academic Press) 2006.
- Monteith J.L. and Unsworth M.H., Principle of Environmental Physics, (Academic Press), 2008.
- Smith C., Environmental Physics (Routledge), 2004.
- Mason N. and Huges P., Introduction to Environmental Physics (Taylor and Francis), 2001.
- Gilbert M., Masters., Introduction to Environmental Engineering and Sciences, (prentice Hall of India), 2008.
- Andrew R. W. and Jackson J. M., Environmental Science- The Natural Environment and Human Impact (Longmon), 1996.

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EN601: FUNDAMENTALS OF ECOLOGY

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Knowledge on ecology, and ecological dynamics.
CO2: Ability to correlate ecological dynamics and regulation of vital processes on earth as biogeochemical cycles.
CO3: Ability to interpret ecosystem services, ecological resilience, ecological economics, and landscape ecology.
CO4: Set up experiments to appreciate concepts of Ecology.
CO5: Critically examine the forces impacting ecosystems like climate change, stress, population, consumerism, globalization, and land use.

Course Content:

- Introduction, foundational concept of ecology and environment, Biotic and abiotic components, ecological dynamics.
- Ecosystem (types and components), ecosystem ecology, ecosystem diversity, niche, habitat, biomes, bioregions, and Eco regions; biogeochemical cycles.
- Hierarchy and levels of organization, population dynamics, interactions among living organisms or ecological communities (interspecific, intraspecific, predation, commensalism, mutualism, symbiosis, coevolution), ecological succession, Invasive species and the threats.
- Ecosystem productivity, energy flow in ecosystems, food chain, food web, food pyramid and nutrient cycling.
- Ecosystem services, ecological resilience, ecological economics, and landscape ecology.

Practical:

- ✓ Assessment of abiotic components in an ecosystem as physicochemical properties in – Atmosphere, Hydrosphere, Lithosphere.
- ✓ Assessment of biotic components in an ecosystem primarily pattern of organisms and habitat exposure.
- ✓ Assessment of biodiversity in a given geographical area – floristic diversity (citing categories of different life forms based on morphological features only).
- ✓ Quadrat study for plants (1m× 1m), involving random sampling to random sampling to measure the abundance, density and frequency of various species in an ecosystem.
- ✓ Field visit and reporting: Forest/desert/aquatic ecosystem – record biotic and abiotic components and interactions.

Recommended Books:

- Kormondy E.J., Concepts of Ecology, Pearson, 2017.
- Odum, E.P. and Barrett, G.W., Fundamentals of ecology (Vol. 3, p. 5). Philadelphia: Saunders, 1971.
- Dash M. C. and Dash S.P., Fundamentals of Ecology, Mcgraw Hill, 2009.
- Ricklefs, R.E. and Miller, G.L., Ecology. W. H. Freeman & Co. 2000.
- Smith, R.L., Smith, T.M., Hickman, G.C. and Hickman, S.M., Elements of ecology. Pearson Benjamin Cummings, San Francisco, CA, 1998.
- Krebs C.J. Ecology: The experimental Analysis of Distribution and Abundance, Pearson, 2016.
- Chew S.C., The recurring dark ages: ecological stress, climate changes, and system transformation. Rowman Altamira, 2006.
- Bharucha E.. Changing Landscapes, The Cultural Ecology of India. Harper Collins Publishers, India, 2017.

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EN602: BIODIVERSITY AND CONSERVATION

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Systematically understand biodiversity and its vital role in ecosystem functions.
CO2: Appreciate the need of biodiversity conservation in the context of various developmental pathways and policy framework that the mankind has been undergoing.
CO3: Identify the importance of biodiversity in natural environments.
CO4: Critically examine biodiversity and human linkages, and help policy formulating for conservation.
CO5: Application of knowledge in general communication for public extension.

Course Content:

- Concept of Biodiversity: Concept and definition, Levels of organization, Dimension of biodiversity, Global biodiversity gradient. List of common flora and fauna of India, endangered and endemic species.
- Values of Biodiversity and ecosystem services: Importance of biodiversity, Direct and indirect used value, Ecosystem Services.
- Biodiversity threats, conservation approaches and management: Decline of biodiversity- causes and consequences, Reason of conservation and conservation approaches, Megadiverse countries, Biodiversity hotspots.
- National Parks, Wildlife Sanctuary, Conservation reserves, Community Reserves, Conservation and management practices, In situ and ex situ strategy,
- Traditional ecological knowledge, Traditionally conserved areas in India: Sacred Groves,.
- Biodiversity and climate changes: Impacts of climate change on biodiversity, Climate change and threats to species and ecosystems, Distribution and adaptation pattern of plants and animals,
- Biodiversity conservation: Legal Instruments Relevant to Biological Diversity in India, Endangered Species Act,
- Major International Conventions: Convention on Biological Diversity, Convention on Migratory Species, Convention on International Trade in Endangered Species of WildFauna and Flora, Ramsar Convention, World Heritage Convention.

Recommended Books:

- Gaston K.J. and Spicer Biodiversity – An Introduction, Blackwell Publishing, 2004.
- Krishnamurthy K. V. Textbook of Biodiversity, CRC Press. 2003.
- Krishnamurthy K. V. An Advanced Textbook on Biodiversity: principles and Practice, Oxford & IBH Pub. Co. Pvt. Ltd. 2008.
- Schulze E-D., Harold M., (Eds.) Biodiversity and Ecosystem Function. Springer-Verlag, London. (1994)
- Khan T. I., Global Biodiversity and environmental Conservation. Pointer Publisher. Jaipur. 2001.
- Magurran A. E., Measuring Biological Diversity. Wiley-Blackwell, Pp-264. 2003.
- Magurran A. E., and McGill B.J.(Eds.) Biological Diversity Frontiers in Measurement and Assessment. Oxford University Press(2010)
- Joshi P. C., Joshi N. Biodiversity and conservation. A.P.H. Pub(2004)
- Melchias G. Biodiversity and conservation. Science, University of Michigan(2001)
- Pandey. B.N. Biodiversity Issues Threats and Conservation. Narendra Publishing(2012)
- Sodhi N. S., and Ehrlich P. R., (Eds.) Conservation Biology for All.Oxford University Press. 2010.
- Maiti P. K. and Maiti P., Biodiversity: Perception, Peril and Preservation, PHI, New Delhi, 2001.
- Bharucha, E. Wonders of Indian Wilderness, Abbeville Press Pub., 2008

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EN603: WATER RESOURCES

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Knowledge of water sources and processes involved.
CO2: Identify the data requirements for water resources and interpret the analysis of the same
CO3: Estimate the design parameters of a water resources system using elementary methods
CO4: Critically examine water resource management systems interaction and significance withrespect to the environment.
CO5: Application of knowledge on water resource technology.

Course Content:

- Inventory of Water Availability around the globe, Hydrologic Cycle and Global Water Balance: Forms of water available in earth, Surface, ground and atmospheric water, Salt water and fresh water.
- Hydrologic Processes: Precipitation – types and forms, Infiltration, Evaporation, Interception, Runoff. Global atmospheric and oceanic circulation and their impact on weather and climate.
- Measurement techniques: Use of Rain-gauges, measurement, interpretation and presentation of precipitation data, Hyetograph and Mass curve of rainfall, Isohyetal maps, Mean precipitation over an area, Measurement of Evaporation, Infiltration and Riverflow.
- Storm Hydrology: Introduction to Catchment area, Surface Runoff and Stream flow; Runoff generation process and governing factors, Hydrograph, Separation of base flow and surface runoff, Unit Hydrograph and its uses, Flood – causes and effects.
- Subsurface hydrology-saturated and unsaturated formation, Ground Water Hydrology: Aquifers and its types, Flow of groundwater in aquifers, Surface and Groundwater interaction.
- Water Resources Projects, Objectives and principles, Irrigation and water supply, Power Generation, Flood Control, Navigation, Recreation, Reservoir projects and their components, Dams, Types of dams, Diversion headwork's, Components and their functions, Run of river projects, Multipurpose projects, Advantage and disadvantages of water resource projects.
- Water scarcity, Water harvesting and management, Frequency and Return period of hydrologic variables, Probability Analysis, Depth-Area-Duration-Frequency relationship of Rainfall.

Practical

- ✓ Estimation of areal and temporal average precipitation/volume of precipitation
- ✓ Field Experiment with Rain gauge to measure precipitation intensity
- ✓ Estimation of evaporation and evapotranspiration
- ✓ Field measurement infiltration and infiltration capacity of soil
- ✓ Field measurement and estimation of flow using current meters

Recommended Books:

- Modi P. N., "Irrigation Water Resources and Water Power Engineering", Standard Book House
- Subramanya, K., "Engineering Hydrology", McGraw Hill Education
- Chow V. T., Maidment D. R., Mays L. W., "Applied hydrology", McGraw Hill Education.
- Garg S. K., "Hydrology and Water Resources Engineering", Khanna Publishers.

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EN604: SOLID WASTE MANAGEMENT

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Understand the characteristic of wastes and the systems, and processes of waste management.
CO2: Identify the case specific issues related to pollution potentials of solid wastes.
CO3: Address solid waste management practices through a cradle-to-grave approach.
CO4: Apply understanding to generate recourses from wastes.
CO5: Make appropriate decisions through application of waste management principles.

Course Content:

- Introduction: Definitions, sources, composition; and generation of - municipal solid wastes (MSW); biomedical wastes; e-waste; and hazardous wastes at national and global scale.
- Environmental impacts: Major pollutants; human health effects; ecosystem damage; air quality; water quality; and soil quality.
- Scientific Management: Principles of solid management; UN conventions (e.g Basel Convention); Collection & transportation measures; Segregation techniques; Pre- cautions; physico-chemical characterization (density, field capacity, particle size, field capacity, pH, organic C, NPK, heat value etc.).
- Techniques of resource recovery: Composting; Microbial decay; Anaerobic digestion; Incineration; Pyrolysis, Landfill gas recovery.
- Environmental regulations: Eco-mark & ISO 14000; symbols & color codes; Solid Waste Management Rules, 2016; Plastic Waste Management Rules 2016.
- Practical: Proximate analysis; Density & Porosity; pH; Organic C estimation; Visit to Landfills & enumeration of waste composition.

Practical:

- ✓ Laboratory experiments: Proximate analysis, Density, Total Organic Carbon, Total Nitrogen, Coliform count.
- ✓ Field visit: Visit to solid-waste and waste-water management sites, sampling, analysis and reporting.

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Recommended Books:

- White P.R. et al, Integrated Solid Waste Management, Lewis Publisher, 1989.
- Manual on Municipal Solid Waste Management, CPHEEO, Ministry of Urban Development, Govt. of India, New Delhi, 2000.
- David L.H.F. and Liptak D. G., Hazardous waste and solid waste, Lewis Publisher, 2000.
- Oberoi N.K, Environmental Management, (2nd Edition) Excel Books, New Delhi, 2003.

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EN605: ENVIRONMENTAL CHEMISTRY

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Comprehensive understanding of the concept of atom, electronic configuration, periodic properties and bonding.
CO2: Appreciation of the fundamental of thermodynamics, chemical equilibrium and chemical kinetics and a comprehensive understanding of the chemistry of water, air and soil, and how human activities pose to alter the chemistry.
CO3: Comprehensive understanding acid-base concepts, neutralization, and buffer and buffer capacity.
CO4: Functional knowledge application on controlling toxic chemicals in the environment emerging pollutants.
CO5: Setting up and conducting experiments.

Course Content:

- Atomic structure, electronic configuration, periodic properties of elements (ionization potential, electron affinity and electronegativity), types of chemical bonds (ionic, covalent, coordinate and hydrogen bonds); mole concept, molarity and normality, quantitative volumetric analysis.
- Thermodynamic system; types of chemical reactions; chemical equilibrium -type and principles, acids, bases and salts, solubility products; solutes and solvents; redox reactions, concepts of pH and pE, Acid- base equilibria, Acid-base titrations, electrochemistry, Nernst equation, electrochemical cells.
- Basic concepts of organic chemistry, hydrocarbons, aliphatic and aromatic compounds, organic functional groups, polarity of the functional groups, and synthesis of xenobiotic compounds like pesticides and dyes, synthetic polymers.
- Composition of atmosphere; measurement of composition, atmospheric particles – chemistry and sources, carbonaceous nature of aerosol, chemistry of and trace gases, reactions of SOx, NOx, Hydrocarbon and surface ozone, Acid rain and case studies; free radicals chemistry, photochemical reactions in atmosphere.
- Fundamentals of Air pollution, smog, types of smog (London smog and photochemical smog), and their chemistry. Chemistry of stratospheric ozone and depletion.
- Chemical and physical properties of water; alkalinity and acidity of water, hardness of water, calculation of total hardness; solubility of metals, complex formation and chelation; colloidal particles.
- Fundamentals of Water pollution – organic matter, oxidation, aquatic microbial/biochemical processes, Acid mine waters, heavy metals, emerging water pollutants, Antibiotic load.
- Fundamentals of soil pollution, POPs, Pesticides, PAHs and PCBs.
- Fundamentals of Green chemistry.

Practical:

- ✓ Analysis of organic carbon, dissolved oxygen (DO), chemical oxygen demand of water samples of a pond.
- ✓ Analysis of nitrate , sulphate in samples.
- ✓ Measurement of acidity and alkalinity, hardness of water Separation of organic mixture by distillation.
- ✓ Separation of compounds by chromatography – paper /thin layer.
- ✓ Field visit: sampling of wastewater/soil/sediment; characterization in the laboratory and reporting.

Recommended Books:

- Manahan S. E, Environmental Chemistry, CRC Press 2010.
- Girard J., Principles of Environmental Chemistry, Jones Bartlett Learning, 2014.
- Harrison R., Principles of Environmental Chemistry, RSC 2007.
- Hanrahan G., Key concepts of Environmental Chemistry, Elsevier Inc. 2012.

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EN606: BASICS OF ENVIRONMENTAL STATISTICS AND COMPUTER APPLICATION

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Knowledge of basic statistical parameters.
CO2: Understand R statistical software.
CO3: Able to perform statistical estimation through R Statistical software.
CO4: Able to perform data processing and visual presentation using R statistical software.

Course Content:

- Introduction, Data presentation, Frequency, Histogram, Basic Statistics (Mean Median, Mode, Standard Deviation, Skewness, Kurtosis), Quantiles, Box, Whisker Plots.
- Concept of population, sample, Sample design, Sample size for data analysis, data quality, Quality control.
- Probability, Probability distribution, cumulative distribution function, parametric distributions and non-parametric distributions, Estimating distribution parameters, Ordinary least square technique, Maximum likelihood estimates.
- Test of Hypothesis, Goodness of fit test, correlation, covariance, cross correlation.
- Test for stochastic trend, Auto correlation function, partial auto correlation function, Bivariate Regression, Multi variate regression, collinearity, Auto regression, Moving average, Auto Regressive Integrated Moving Average model.

Practical:

- ✓ R software Introduction, software Module download, Data entry into R Work station, Matrix operation, Statistical Plots generation, Simple statistical analysis in R, Small programme development in R, Test of Hypothesis.
- ✓ Case studies from Different domain of Environment such as air, water, soil and Biodiversity etc.

Recommended Books:

- Spiegel M., Stephens LJ, Schaum's Outline of Statistics, McGraw Hill.
- Forsyth D., Probability and Statistics for Computer Science, Springer.

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EN701: ENVIRONMENTAL POLLUTION AND HUMAN HEALTH

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Knowledge on the types and the science of environmental pollution.
CO2: Appreciation of the effect of polluting on human health.
CO3: Analytical ability to link cause and effect of pollution .
CO3: Critical issues of handling pollution vis a vis human being.
CO3: Ability to develop pollution mitigation/abetment strategies.

Course Content:

- Environmental pollution – definition, local, regional and global implications, effects of environmental pollution
- Air Pollution: Introduction, air pollutants, types and sources, history of air pollution episodes, air pollution and effects on human health, Air pollution Public health matters, Air pollution source apportionment, regulation, and mitigation.
- Water pollution-introduction, sources of water pollutants, Agriculture and Water pollution, Problems of pesticides and chemical fertilizers, Sanitation and Drinking Water, waterborne diseases, Wastewater Treatment and Water Reuse, Implications on health – appreciation of Minamata disease, itai itai disease, blue baby syndrome.
- Noise pollution: Introduction, noise categories, Noise effects - hearing loss, Cardiovascular effects, Psychological impacts, Stress, Annoyance, effects on Child development Cognitive development, control of noise pollution and regulation.
- Land pollution: causes and consequences, MSW – characterization, and impact on public health, emission from waste dumping sites, leaching, biomagnification, Agriculture and land pollution, Land management through phytoremediation and bio-remediation; Biological mediated pollution control.

Practical:

- ✓ Measurement of particulate matter in air by grab sampling and gravimetric method. Understanding levels of SOx and NOx in ambient air.
- ✓ Sampling and analysis of organic matter, nitrate, sulphate, TDS and COD of waste water/ contaminated soil.
- ✓ Understanding and comparing noise levels of localities.
- ✓ Field visit: Visit to a local polluted site-Urban/Rural/Industrial/Agricultural, sampling, analysis and reporting, Visit to industry having air-pollution control measures and reporting.

Recommended Books:

- Shaw I.C. and Chadwick J., Principles of Environmental Toxicology, Taylor& Francis, 2008
- Manahan S.E., Environmental Chemistry, Lewis, 1994
- De A. K., Environmental Chemistry, Wiley Eastern Limited, 2000
- Moore J. W., Inorganic Contaminants of Surface Water, Springer-Verlag
- Gurjar B. R., Molina L.T., Ojha C.S.P. (Eds.), Air Pollution: Health and Environmental Impacts, CRC Press
- Elaine M.A. and Bugyi G.(Eds.), Impact of Water Pollution on Human Health and Environmental Sustainability, Information Science Ref.

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EN702: ENVIRONMENTAL INSTRUMENTATION

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Knowledge of analytical instrumentations.
CO2: Appreciate outputs of analytical data.
CO3: Skill developed in the field of environmental instrumentation and analyses.

Course Content:

- Basics principles of analytical instruments - spectroscope, diffraction, chromatography, electronic transition, fundamentals of optics and photometry, principles of microscopy.
- Spectroscopy: Introduction, basic principles, Types of spectroscopy, Absorption spectrum, Emission spectra, Electromagnetic radiation, Beer-Lambert's law, UV-Visible spectroscopy, Fluorescence spectroscopy, IR/Raman spectroscopy, Flame Photometry, Atomic Absorption Spectroscopy, NMR Spectroscopy and Mass spectroscopy.
- X-ray diffraction: X- ray spectra, Bragg's law, XRD techniques.
- Gas Chromatography: Principle, carrier gas, stationery phase, instrumentation, sample injection, column detectors (TCD, FID, ECD), effect of temperature on retention, qualitative and quantitative analysis.
- High Performance Liquid Chromatography: Principle, instrumentation, column, sample injection, detectors (absorbance, refractive index, electrochemical), mobile phase selection, ion pair chromatography.
- Introduction to sampling techniques to measure environmental contamination in air, water, soils, and food. Safe Laboratory Practices, Quality assurance and Quality control.

Practical:

- ✓ Measurement of ambient noise
- ✓ Measurement of atmospheric dust.
- ✓ Calibration and measurement of pH, Conductivity Measurement light absorbance Vs concentration (Beer's law).
- ✓ Constructing a calibration curve from chromatograms of calibration standards Analysis of IR spectra of simple compound.
- ✓ Analysis of NMR simple compounds.
- ✓ Analysis of Mass spectra of simple compounds Microscopy of environmental samples.
- ✓ Field visit: Visit to a national laboratory (CSIR Lab) to see sophisticated instrumentation facilities. Demonstrations for the students may be organized on request.

Recommended Books:

- Skoog D. A. and Crouch S. R., Principles of Instrumental Analysis (7th Edition).
- Ewing G. R., Instrumental Methods of Chemical Analysis (5th Ed.), McGraw Hill.
- Rouessac F., Rouessac A., Chemical Analysis: Modern Instrumentation Methods and Techniques, Wiley.
- Kemp W., Organic Spectroscopy, Palgrave Macmillan, 1991.

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EN703: ENVIRONMENTAL LEGISLATION AND POLICY

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Understand the Indian constitutional provisions with respect to the environmental protection, division of powers, and fundamental rights.
CO2: Appreciation of forest and wildlife laws and environmental laws relating to social justice (Forest Dwellers' Act of 2006; The Biodiversity Act of 2002).
CO3: Comprehensive understanding of pollution control laws (The Water Act, The Air Act and the Environment (Protection) Act of 1986), and rules.
CO4: Functional understanding of international Environmental laws (Treaties and Protocols), and Indian commitments.
CO5: Appreciate some case studies of environmental litigation.

Course Content:

- The Constitution of India and provisions – Article 48A; Article 51 A(g, The right to livelihood, The right to a Wholesome Environment, Division of power between the Centre and the States in matters of forest and wildlife, and water.
- Forest and Wildlife laws: The Indian Forest Act 1927; The Wildlife (Protection) Act 1972; The Forests (Conservation) Act 1980,
- Laws for pollution control and Environmental Protection: The Water (Prevention and Control of Pollution) Act 1974; The Air (Prevention and Control of Pollution) Act 1981; The Environment (Protection) Act 1986; Noise Pollution (Regulation and Control) Rules 2000,
- Laws for social equity and justice: ; The Biological Diversity Act 2002 The Schedule Tribes and other Traditional Dwellers (Recognition of Forests Rights) Act 2006;The Public Liability Insurance Act 1991;
- International environmental laws, Major conventions and treaties: The Stockholm Declaration of 1972; United Nations Conference on Environment and Development 1992; Montreal Protocol 1987; Kyoto Protocol 1997; Paris summit.

Recommended Books:

- Divan S. &Rosencranz A., Environmental Law and Policy in India. OUP, 2001.
- Naseem M., Environmental Law in India Mohammad. Kluwer Law, 2011 International.
- Venkat A. Environmental Law and Policy. PHI, 2011
- Sands P., Peel J., Principles of International Environmental Law, CUP 2018
- Abraham C.M. Environmental Jurisprudence in India. Kluwer Law International. 1999.

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EN704: ATMOSPHERIC PROCESSES

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Knowledge of structure and composition of the atmosphere and explain global atmospheric circulation.
CO2: Understand the processes involved in the mixing and transport of constitutes against varied stability conditions.
CO3: Recognise major geochemical processes involving cycling of constituents.
CO4: Recognise major chemical/ photochemical pathways of organic and inorganic gases and their implications including acid rain, smog, ozone depletion, visibility impartment.
CO5: Application of knowledge in appreciating the atmosphere of large cities and global atmospheric issues.

Course Content:

- Atmosphere: composition and structure, mass, Atmospheric pressure, vertical profile of temperature and pressure.
- Atmospheric transport, geostrophic flow- Coriolis force, Geostrophic balance, circulation, Vertical transport –temperature lapse rates, Stability, types of stability, latent heat and cloud formation, concept of PBL.
- Turbulence – Definition, Turbulent flux, Parameterization of turbulence.
- Concepts of diffusion, dispersion, Ideas of Eulerian approach, Langrangian approach, The Gaussian plume equation.
- Geochemical Cycles, The Carbon, nitrogen and oxygen cycles, Mass balance of atmospheric CO_2.
- Chemical Kinetics – principles of gas phase reactions, rate expressions, Bimolecular reactions, Three-body reactions, reversible reactions and equilibria, Photolysis, free radical reactions.
- The stratosphere – the ozone layer, the Chapman mechanism, catalytic ozone loss, agents of loss process, mechanisms, Polar ozone loss- mechanism, PSC formation, The ozone hole.
- The greenhouse effect- fundamental of radiation, Solar and terrestrial emission spectra, Radiative balance of the Earth, behaviour of gas molecules- CO_2, H2O, Methane, etc. and particles.
- Concepts of atmospheric scattering and diffraction, radiative forcing - definition and application, effect temperature, water vapour and cloud feedbacks, Optical depths, Weather and Climate- tropical weathers and extreme weathers.
- Climate change- causes, effects and mitigation/ adaption.

Practical:

- ✓ Determination of Rainfall using rain gauge
- ✓ Analysis of rainfall data (hourly, weekly, monthly, annually)
- ✓ Determination of relative humidity, light intensity and atmospheric pressure.
- ✓ Collection and Analysis of Wind Data, Wind Roses, Plotting of Wind Roses and Pollution Roses.
- ✓ Analysis of gaseous and particulates in ambient air
- ✓ Analysis of Greenhouse gases

Recommended Books:

- Jacob D. J, Introduction to Atmospheric Chemistry, Princeton, 2004.
- Seinfeld J. H. and Pandis S.N., Atmospheric Chemistry and Physics. Wiley 2006.
- Hobbs P. V., Introduction to Atmospheric Chemistry, CUP 2000.
- Finlayson-Pitts and Pitts, Chemistry of the Upper and Lower Atmosphere, Academic Press, 2000.
- Wallace J. M. and Hobbs P. V., Atmospheric Science: An Introductory Survey, Academic Press, 2006.
- Barker J. R., Steiner A. L, Wallington T. J (Eds.), Advances In Atmospheric Chemistry Vol-1, World Scientific 2017.
- Jacob D. J. and Brasseur G., Modelling Atmospheric Chemistry, CUP 2017.

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EN801: WILDLIFE CONSERVATION AND MANAGEMENT

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Understand basic ecological principles (the interconnectedness of organisms to each other and their environment) to environmental problems and sustainability issues.
CO2: Articulate fundamental concepts in wildlife conservation and management.
CO3: Apply understanding of cultural, historical, and current perspectives on the human-wildlife relationship to effectively address wildlife issues.
CO4: Identify the primary international, national, and state agencies and scientific organizations, responsible for conservation and management of wildlife, and understand the role of private citizens in decision-making at all levels.
CO5: Make informed decisions about wildlife conservation and management by critically evaluating information sources.
CO6: Appreciate current threats to biodiversity.
CO7: Be capable of assessing status of wildlife and biodiversity.

Course Content:

- Introduction: Definition of wildlife (instrumental, intrinsic, ecocentric, religious, conservational); Indian wildlife; Protected areas in India; Legal instruments; Threats to wildlife; Wildlife trade and role of CITES.
- Overview of protected areas in India: Biodiversity within an outside protected areas and in protected areas.
- Threats to wildlife– extinction, island biogeography, endemic and endangered species and vulnerability to extinction, habitat destruction, fragmentation, exotic species and invasive, lots of biodiversity.
- Conflicts between man and wildlife: Elephant-man conflict; Rhino-man conflict; River dolphin-man conflict; Tiger-man conflict; Leopard-man conflict; Conflict management and shifting from extraction to preservation; Response system between human-wildlife conflict.
- Wildlife heath monitoring: Rescue measures for wounded animals; First aid for animal injuries; Animal health management; Population viability and habitat analysis (PVHA); National and International organizations involved in wildlife health management.
- Current issue in wildlife conservation: Community based conservation vs. rare species conservation; Climate change and wildlife movement; Ecological services of wildlife; Ecotourism and wildlife; Habitat fragmentation and wildlife corridors.
- Sustainability in wildlife management: Collaborative partnership for sustainable wildlife management; Voluntary relocation of local communities; Use of barriers, deterrents, and alternative cropping on wildlife management; Land-use planning; Shared governance, education and awareness-raising.

Practical:

- ✓ Orientation to field biology and natural history
- ✓ Observations and collection of study material, wildlife signs and evidences.
- ✓ Exercise on wildlife population parameters and census methods for various species.
- ✓ Types of sampling- quantitative , qualitative for flora and fauna
- ✓ Estimation of frequency, density, abundance of species.
- ✓ Field tour designed to examine wildlife conservation issues in a variety of ecological situations in a bio-geographic zone of India.
- ✓ Assignments, seminars, and report at the end of the course.

Recommended Books:

- Saha, G.K., and Majumdar, S. Wildlife Biology: An Indian Perspective, Prentice Hall of India. 2017.
- Kaushik, A., and Garg, G. Perspectives in Environmental Studies, New Age Publishers. 2018.
- Rangaraj, M. India's Wildlife History: An Introduction, Oxford Press, 2006.
- Rangaraj, M. and Sivaramakrishna, K. Shifting Ground: People, Animals and Mobility in India's Environmental History, Oxford Press, 2014.
- Bindra, P.S. The Vanishing: India's Wildlife Crisis, Penguin Books. 2017.
- Sinha, S. Handbook on Wildlife Law Enforcement in India, WWF Press. 2011.

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EN802: INTRODUCTION TO CLIMATE CHANGE

L5T1 P0 CH6 CR6

Course Outcomes:

CO1: The students will learn about the origin, composition and structure of the atmosphere and the linkage of atmospheric parameters with the global climate change. CO2 Articulate fundamental concepts in wildlife conservation and management.
CO2: They will learn about the casual gases and mechanism of global warming and understand how the climatic of the earth had changed in the geological history.
CO3: The students will also learn about various impacts of climate change of the organisms, human and ecosystem and the policy response and mitigation strategies adopted worldwide. CO5 Make informed decisions about wildlife conservation and management by critically evaluating information sources.
CO4: The practical component will give the students basic ideas about how to collect atmospheric data, measure atmospheric GHGs concentrations and link the information to understand and resolve the problems of climate change.

Course Content:

- Atmosphere – origin, composition, structure, insolation and heat budget; Basic atmospheric properties, Climatic classifications, Monsoon, El-nino, Southern Oscillation, cyclones, Milankovitch Cycle, Gia hypothesis.
- Global atmospheric temperature, Greenhouse gases – global and regional trend in GHGs emission, role of aerosol, ozone and trace gases; Global warming, Climate change, Climate variability in geological history, natural and human induced climate change.
- Impact of climate change on organisms, human, ecosystem, agriculture and food security; Sea level rise, Coral bleaching, Extinction risk of temperature sensitive species, melting of snow, ice and glaciers.
- Policy response and mitigation strategies; UNFCC, Kyoto Protocol – Carbon credit, Carbon trading, carbon sequestration, CDM; Clean energy options; CFCs – uses and trends; Reducing Carbon footprint.

Recommended Books:

- Archer, D., (2007) Global Warming: Understanding the Forecast. Blackwell Publication
- Bahadur (2004).Himalayan Snow and Glaciers, Concept Pub
- Byers, H.R. (1974).General Meteorology , McGraw-Hill
- Dash, S. K. (2007) Climate change: An Indian Prespective. CEE, Ahmedabad
- Lal, D.S. (2004). Climatology, Chaitanya Publishing House, Allahabad.
- Master, G. L. (2001) Introduction to Environmental Engg. and Sc. Pentice Hall of India, New Delhi.
- Oke, T.R. (1978). Boundary Layer of Climates, Methuen & Co. Ltd
- Pal Arya, S. (1988).Introduction to Micrometeorology, Academic Press
- Petterssen, S. (1978) Introduction to Meteorology. McGraw Hill book Company, Inc. London.
- Thomas E. L., and Hannah L. J. (2006) Climate change and Biodiversity. Yale University Press
- Trewartha, G.T. (1974).General Meteorology, McGraw-Hill
- Wallace J.M. & Hobbs, P.V. (1977).*Atmospheric Science – An Introductory Survey*, Academic Press.

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EN803: ENERGY AND ENVIRONMENT

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Understanding of solar radiation's spectrum and the energy available from solar radiations.
CO2: Should be able to make a distinction between conventional and renewable energy sources.
CO3: Understanding of the principles of energy conversion in case of each of the energy sources.
CO4: Should be able to state how the consumption of fossil fuels and biomass leads to adverse impact on health and climate.
CO5: Should have an understanding of the implications of large scale production of power from sources such as hydro, solar, wind etc.
CO6: Should become aware of the government's energy policy.

Course Content:

- Introduction: concepts of energy, power, heat and work, potential energy, kinetic energy, conservation of energy; energy conversion factors, global energy flows, sun's radiations, energy budget of earth atmospheric system, energy in biosphere, photosynthesis, energy flow in an ecosystem, human influence on energy flows.
- History of energy use sectorial consumption of energy, energy consumption with time, population growth and projections for future.
- Sources of energy: Conventional and nonconventional sources, fossil fuels-coal, gas and oil and their properties, renewable sources-solar (flat plate and Photovoltaic), wind, hydro, ocean thermal, geothermal, tidal, biomass, nuclear, biofuels and the principles of energy generation, fuel cells, hydrogen energy.
- Environmental implications of energy use: air pollution from fossil fuels and biomass, impacts on climate change and health, impacts of large scale use of energy from solar, wind, hydro, ocean thermal energy, geothermal sources and nuclear energy. Thermal pollution-cooling towers, cooling by river water, lakes and ocean, radioactive waste, oil spills. CO2 emission reduction potential from use of renewable energy.
- Energy storage devices, efficiency of energy use and energy policy of the country. Current status of installed capacity and potential of renewable energy sources.

Recommended Books:

- Thorndike E. H., Energy and Environment- A Primer for Scientists and Engineers (Addison Wesley, Publishing) 1976.
- Devins D. W., Energy and its Physical Impact on Environment (John Wiley & Sons) 1982.
- Raven P. H. and Berg L. R. Environment (John Wiley & Sons)
- Gilbert M. Masters, Introduction to Environmental Engineering and Sciences (prentice Hall of India) 2008.
- Tindell J. W. and Weir A. D., Renewable Energy Resources (ELBS)
- Shonley J. I. Environmental Applications of General Physics V(Addison Wesley, Publishing)
- Andrew R. W. and Jackson J. M., Environmental Science- The Natural Environment and Human Impact (Longmon) 1996.
- Boyles D. T., Bio Energy: Technology, Thermodynamics and Costs (Ellis Horwood Ltd, John Wiley and Sons) 1984.
- Wilson R. and Jones W., Energy, Ecology and Environment (Academic Press, Inc) 1974.
- Dunderdale J., Energy and Environment (Royal Society of Chemistry) 1990.

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EN804: NATURAL HAZARDS AND DISASTER MANAGEMENT

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Understand the different types of natural hazard, their major driving forces/factor, and the causes.
CO2: Understand the relationship/interface between geophysical processes and human activities in causing natural hazard.
CO3: Hazards Scenario at the global as well as National level.
CO4: Understand the mitigation approaches, their choices and alternatives CO5 Develop foundations for hazard, risk and vulnerability assessment.

Course Content:

- Definitions and associated concepts: natural hazards, risk, vulnerability; Hazards and risk assessment.
- Floods: floods as physical process (river systems, runoff, river activities); causes and factors of flooding, effects of /hazards associated with flooding; response to flood hazards; global and India scenario.
- Earthquake: origin of earthquakes; seismic waves; world's seismicity with emphasis on Indo-Burma region; hazards associated with earthquakes; response to earthquake hazards.
- Drought: Cause and impact; types of draughts (meteorological, hydrological, agricultural and socio-economic) response to hazards- mitigation and adaptation; droughts in India.
- Cyclones: Genesis; tropical cyclones- formation, frequency and trajectory; impact of cyclones, mitigation and adaptation.
- Landslides: Genesis (slope failure mechanism); causes of landslides, prevention and correction methods; Global and Indian scenario.
- Disaster: definition, causes, natural and man-made, effects- immediate and delayed, disaster management and case studies

Practical:

- ✓ Slope stability analysis for landslide study
- ✓ Analysis of seismographs to estimate epicenter of earthquake
- ✓ Flood Frequency analysis
- ✓ Unit hydrograph analysis
- ✓ Probability plots and estimation of floods
- ✓ Assessment of drought situation of an area

Recommended Books:

- Bell F.G., Geological Hazards: Their Assessment, Avoidance & Mitigation, Taylor and Francis, 2003.
- Alexander D., Natural Disasters, ULC press Ltd, London, 1993.
- Bryant E., Natural Hazards, 2nd Edition, Cambridge University Press.
- National Policy on Disaster Management, NDMA, New Delhi, 2009.
- A Global Report - Reducing Disaster Risk, A Challenge for Development; UNDP Publication, 2004

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11. DETAILED SYLLABUS (DISCIPLINE SPECIFIC COURSE)

EN711: ENVIRONMENTAL ECONOMICS

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Know the concepts of market and the economics of the environment.
CO2: Identify economic solutions to environmental problems and the role of environmental market based instruments.
CO3: Apply of economic theories to analyze environmental problems and solutions.
CO4: Appreciate risk analysis in providing economic solutions to environmental problems.
CO5: Apply economic analysis in environmental decision making process.

Course Contents:

- Introduction: History and fundamental concept of environmental economics; introduction to economic theories and economic approach to real world environmental problems.
- Depletion of natural resources, climate change impacts, degradation of environmental quality, solid and toxic wastes, best management practice and sustainable development, national and international agreements.
- Environmental goods, public goods, private goods, common property resources, economic valuation, concept of market, market failure, social costs, private costs, externalities.
- Economic Solution, policy instruments and environmental markets, environmental market based instruments: pollution charge, subsidy, deposit refund system and pollution permit trading system; scenario of environmental market worldwide.
- Economic analysis vis-à-vis benefit-cost analysis in environmental decision making – present value, future value, inflation correction; comparing environmental benefits and costs.
- Risk analysis: risk assessment and risk management.
- Case studies: air quality regulation, water quality regulation, solid and toxic waste regulation.
- Economic issues of ABS(Access Benefit Sharing) as per Biodiversity Act 2002.
- Concepts related to Life Cycle Assessment of products and economic concerns.
- Methods of assessing Natural Capital of economic terms.

Recommended Books:

- Field, B.C. and Field, M.K., Environmental economics: an introduction. Sustainable Human Development Review, 105, 1997.
- Singh, K. and Shishodia, A., Environmental economics: Theory and applications. SAGE Publications India, 2007.
- Andersen, M.S. and Sprenger, R.U. eds., Market-based instruments for environmental management: politics and institutions. Edward Elgar Publishing, 2000.
- Quah, E. and Haldane, J.B.S., Cost-benefit analysis. Routledge, 2007.
- Willis, G. and Garrod, K.G., Economic valuation of the environment. Methods and case studies. Environ Res Econ, 21, pp.101-102, 1999.

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EN712: SOIL CONSERVATION AND LAND MANAGEMENT

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Understand principles of water and land management.
CO2: Describe the basics of hydrology, soil conservation, groundwater, irrigation and drainage, and watershed.
CO3: Understand impact of human action on soil and land.
CO4: Critically examine the issues of Soil and Land in the environmental perspectives.
CO5: Apply knowledge in water and land conservation projects.
CO6: Natural forest, grassland, wetland etc. Eco restoration techniques and case.

Course Content:

- Introduction: Engineering in land and water management, land and water management and agricultural production, soil and water conservation, groundwater and wells, irrigation and drainage management, watershed management, environmental management, concept of sustainable development.
- Land resources for agriculture: Land classification, land capability classification, USDA system, land evaluation (US system of soil taxonomy), FAO framework for land evaluation, land degradation, land improvement, agro climatic zoning.
- Hydrologic cycle: Components, precipitation, rainfall-rain gauges, analysis of rainfall data, frequency, average depth, runoff-factors affecting, methods for estimation, runoff hydrograph, unit hydrograph.
- Water measurement: Fundamental equations, measurement of flow in open channels- velocity area methods, directmethods, measurement of flow in pipes- volumetric measurement, flow rate measurement, water level recording equipment.
- Salt affected soils, Soil erosion- effects, causes, types, factors affecting, measurement of soil loss and sediment yield, USLE. Soil erosion control- agronomical and structural measures- contour cultivation, strip cropping, contour trenching, bunding, bench terracing. Wind erosion and its control, stream bank erosion and its control, gully erosion and its control.
- Integrated Watershed management:
- Ecorestoration:

Practical:

- ✓ Determination of Rainfall using rain gauge
- ✓ Analysis of mass curve and hyetograph
- ✓ Analysis of rainfall data (hourly, weekly, monthly, annually)
- ✓ Preparation and labeling the various parts of hydrograph using the discharge data
- ✓ Comparative study of agricultural soil and forest soil
- ✓ Study soil textures of different soil samples to determine the type of soil
- ✓ Study rate of erosion in vegetated soil and non-vegetated soil
- ✓ Study of soil moisture content in different soil types (sand, silt and clay)
- ✓ Study of water holding capacity of different soil types (sand, silt and clay)
- ✓ Study of soil bulk density

Recommended Books:

- Moorthy V. V. N., Land and water management, Kalyani, 2006
- Larsson G. , Land Management as Public Policy, University Press of America 2010
- Howell E. A., Harrington J. A., Glass S. B., Introduction to Restoration Ecology , Island Press, Washington, United States, 2011.

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EN713: SOIL REMEDIATION AND RESTORATION

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Ability to think and function as a prudent professional soil scientist.
CO2: Generate and analyze soil quality data towards sustainable solutions.
CO3: Apply the gained knowledge to practical situations.
CO4: Ability to respond flexibly towards restoration of problematic soils of specific areas.
CO5: Demonstrate and train farmers/growers to establish sound soil quality maintenance practices.

Course Content:

- Soil Formation: Weathering and Soil formation; Profile development; Soil composition; Soil forming rocks and minerals; Classification.
- Soil Physico-chemical properties: Soil texture and structure; Soil separates and particle size distribution; Bulk density, particle density, pore space, soil water; Soil colloids; pH, Eh, CEC, base saturation.
- Problem soils: Nature and extent of problem soils in India; Soil erosion and desertification: Soil erosion (definition, mechanism of water and wind erosion); Nature and extent of desertification in India; cause and effects on agriculture and sustainability issues.
- Soil & Plant relations: Soil organic matter; Decomposition; Humus formation; Significance on soil fertility, nutrient availability.
- Physico-chemical properties of acidic soils, saline soils, alkaline soils, acid-sulfate soils.
- Soil pollution: Heavy metal pollution; organic pollutants in soil; impacts on soil micro-organisms; bio-indicators of soil pollution.
- Remediation measures: Treatment of problem soils (liming, salt eradication, treatment of saline and alkaline soils); heavy metal removal/localization, Phytoremediation and Bioremediation of soil.
- Restoration: Vegetation recovery (tolerant species, using hyperaccumulators, etc.); soil organic matter application; mulching; mechanical measures (contour trenching, contour mulching, drainage, etc.).

Practical

- ✓ Basic methods of soil sampling
- ✓ Determination of basic soil physical parameters (Soil moisture, Soil texture, soil composition, bulk density, porosity, WHC,
- ✓ Particle size of soil by hydrometer method etc.)
- ✓ Determination of Soil pH, EC, CEC. pH, EC, Alkalinity,
- ✓ Determination of Organic Carbon, Nitrogen, Phosphorous, Potassium in Soil
- ✓ Determination of soil microbes, isolation and identification of soil microbes
- ✓ Determine the sodium adsorption ratio of soil.
- ✓ Estimation of heavy metals in a given soil sample

Recommended Books:

- Arakeri H.R. and Roy D.; Principles of Soil Conservation and Water Management; Oxford IBH Pub. Co. Pvt. Ltd.; 2000.
- Brady N.C., and Weil R.R. Elements of the Nature and Properties of Soils, 3rd Ed. Prentice Hall, 2010.
- Stewart B.A., Advances in soil sciences, Lewis Publisher, 2000.
- Biswas T.D. and Mukherjee S.K., Textbook of Soil Sciences, Publisher: McGraw-Hillo Inc., US, 2nd edition, 1995.

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EN714: ENVIRONMENTAL MODELLING

L5 T1 P0 CH8 CR6

Course Outcomes:

CO1: Understand mathematical and statistical concepts required for model development.
CO2: Understand different environmental systems, their components, processes and their interconnections.
CO3: Perform data exploration and visualization.
CO4: Understand the importance and implications of quantifying uncertainty in environmental assessment, modeling.
CO5: Test model performance in terms of statistical error estimation.

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Course Content:

- Introduction: Principles of model development, Types of models, Physical models, Statistical Models, Conceptual models, basic elements of Model building.
- Mathematical Concepts: Matrices, system of linear equations, Series and sequences, Difference Equations, Differential and partial differential equations, Integrals (Line, area and volume), Permutations, Combinations, Simple Probability, Conditional probability, Probability distributions,
- Environmental System and Processes: Natural and artificial systems, characters and components of the system, measures and concentrations, processes categories, transport process, transformation processes.
- Model Framework: Stochastic Models, Dynamic models, Approaches to modelling, Uncertainty measurement, Model Verification and validation, Model feedback systems.

Recommended books:

- William G. Gray W.G. and, Gray G.A., Introduction to Environmental Modeling, CUP.
- Holzbecher E., Environmental Modeling: Using MATLAB, Springer.
- Wainwright J., Mulligan M (Ed) Environmental Modelling: Finding Simplicity in Complexity, Wiley.

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EN811: WATER TREATMENT TECHNOLOGY

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Select the sources of water for various water uses.
CO2: Explain unit operations and processes of water treatment systems.
CO3 Apply the principles and design water treatment units.
CO4: Apply concepts and will be able to design the water treatment plant.

Course Contents:

- Introduction, Population Forecasting and Water Demand.
- Water Quality: Definitions, Characteristics and Perspectives.
- Physical water quality parameters, Chemical water quality parameters, Biological water quality parameters, water quality requirement, water quality guidelines and standards for various water uses.
- Water Purification process in Natural system.
- Physical process, Chemical process, Biochemical processes, response of stream to biodegradable organic waste, application of natural processes in engineered system.
- Engineered systems of water purification.
- Overview of water treatment, water treatment process.
- Aeration: Principles and design of aeration systems –two film theory, water in air system, air in water system.
- Solid Separation and settling operations: principles of sedimentation –types of settling and settling equations, design criteria and design of settling tanks.
- Coagulation and Flocculation: Principle of Coagulation and Flocculation –types of coagulants, coagulant aids, coagulation theory, optimum dose of coagulant, design criteria.
- Filtration: Types, hydraulics of filter bed, design criteria and design of filters, filter backwash, operational problems and trouble shooting.
- Disinfection: Types of disinfectants, factors affecting disinfection, methods of disinfection, chemistry of chlorination.
- Water Softening.

Practical:

- ✓ Laboratory experiments: Alkalinity Test; Turbidity Test; pH and Conductivity Test; Estimation of Hardness; Estimation of BoD and CoD; Estimation of residual chlorine.
- ✓ Field Visit: Visit to a water treatment site, sampling, analysis, and reporting on the same; Visit to a STP or ETP site and reporting.

Recommended books:

- Garg S.K., Water Supply Engineering (Vol-I & II), Khanna Publishers
- Peavy H.S., Rowe D.R. & Tchobanoglous G., “Environmental Engineering”. McGraw Hill International Edition.
- Karia G.L., Wastewater Treatment: Concepts and Design Approach, PHI, 2013
- McGhee T. J., “Water Supply and Sewerage”, McGraw-Hill, Inc., 1991.
- Davis M. L. & Cornwell D. A., “Introduction to Environmental Engineering”, McGraw- Hill, Inc.,1991.
- Metcalf & Eddy, “Wastewater Engineering- Treatment and Reuse,” Tata McGraw Hill, 4thEdn., 2003.
- Sawyer C. N., McCarty P. L., Parkin G. F., “Chemistry for Environmental Engineers”, McGraw-Hill, 1994.
- Punmia B.C., Environmental Engineering (Vol-I & II), Laxmi Publishers.

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EN812: AIR POLLUTION MONITORING AND CONTROL

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Able to differentiate between primary and secondary pollutants.
CO2: Familiarise with different sources and sinks of common air pollutants.
CO3: Develop understanding about different types of monitoring techniques available for gaseous and particulate matter.
CO4: Able to do sampling and analysis of air pollutant.
CO5: Develop an understanding of working of air pollution control devices.

Course Content:

- Introduction: Definitions, types of air pollutants, Sources of air pollution: Point source, area source, Volume source; criteria pollutant, Air Quality Index, Ambient air quality standards, Vehicle emission standards.
- Air pollution meteorology, Atmospheric Reactions and Scavenging processes.
- Effect of Air pollution on plants, animals, humans, biodiversity, agriculture etc,
- Air pollution sampling methods: Sampling from point sources (Stack Monitoring, vehicles), ambient sampling methods. Online and offline sampling instruments for gaseous and particulate air pollutants.
- Air pollution control methods: industrial source control technology: Cyclone, Electrostatic Precipitator, Baghouse Filter, Venturi Scrubber – principle and use, its limitations.

Practical:

- ✓ Monitoring of Total Suspended Particulate Matter (TSPM); monitoring of SO2, NO2, NH3, CO and O3.
- ✓ Exposure analysis of SO2, NO2 and CO, to plants leaves.
- ✓ Field Visit to nearby industries for studding different control technology.

Recommended books:

- Allegrini I, DeSantis F. (Ed), Urban Air Pollution: Monitoring and Control Strategies, Springer.
- Clarke A.G., Industrial Air Pollution Monitoring, Springer.

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EN813: ENVIRONMENTAL BIOTECHNOLOGY

L4 T0 P2 CH6 CR6

Course Outcomes:

CO1: Knowledge on scope of biotechnology in environmental applications CO2 Knowledge of microbiology and biochemistry.
CO3: Ability to perform various molecular biological applications, and knowledge of equipment used in molecular biological techniques.
CO4: Ability to apply molecular biological techniques in pollution management and industrial applications.
CO5: Knowledge of advanced biotechnological applications, and biosafety in analytical procedures.

Course Content:

- Introduction: Introduction and history, scope of environmental biotechnology.
- Biochemistry and molecular biology: Cell as a unit of life, molecular genetics – nuclear material, central dogma, replication, repair and recombination of genetic material, translation, transcription, mutation.
- Microbiology and industrial applications: classification of microorganisms, microorganisms in extreme environment, pathogenic and useful microorganisms, microbial enzymes in industrial applications; involvement of microorganisms in fermentation; production of biofertilizers, biogas, bioethanol and biopolymers; and food industry.
- Biotechnological applications in pollution management: solid waste management and waste water treatment; role of microorganisms in sewage treatment and degradation of municipal solid waste; degradation of plastics and polymers using microorganisms.
- Environmental remediation: Bioremediation-remediation of toxic compounds using plants and microorganisms; Nanobiotechnology – green synthesis of nanomaterials, application of nanomaterials in combating environmental pollution.
- Biosafety in analytical procedures.

Practical:

- ✓ Study laboratory equipment – Compound Microscope; Laminar Air Flow, Autoclave, Spectrophotometer and other basic equipment used in the laboratory.
- ✓ Preparation of different culture media, sterilization of media, pour plate techniques, solid media in test tubes; microbial culture, inoculation techniques, streaking, spreading and replication; microbial cell counting by serial dilution technique and pour plate technique Identification of microorganisms through biochemical tests (bacteria/fungi/virus); screening of useful microorganisms from several hosts/extreme environment (example – cellulose producing microorganism).
- ✓ DNA extraction and purification techniques.
- ✓ Study of alcoholic and mixed acid fermentation techniques.

Recommended Books:

- Jördening, H.J. and Winter, J. eds., Environmental biotechnology: concepts and applications. John Wiley & Sons, 2005.
- Singh, B.D. and Singh, B.D., Biotechnology expanding horizons. Kalyani publishers. 2007.
- Lehninger, A.L., Nelson, D.L., Cox, M.M., Lehninger principles of biochemistry. Macmillan, 2005.
- Elliott, W.H., Elliott, D.C. and Jefferson, J.R., Biochemistry and molecular biology (Vol. 2001, p. 586). Oxford: Oxford University Press, 1997.
- Wang, L.K., Ivanov, V., Tay, J.H. and Hung, Y.T. eds., Environmental biotechnology (Vol. 10). Springer Science & Business Media, 2010.
- Rittmann, B.E. and McCarty, P.L., Environmental biotechnology: principles and applications. Tata McGraw-Hill Education, 2012.
- Patel A.H., Industrial microbiology. Macillan India Ltd, 2000.
- Nalwa, H.S. ed., Nanostructured materials and nanotechnology: concise edition. Elsevier, 2001.
- Doble, M., Kruthiventi, A.K. and Gaikar, V.G., Biotransformations and bioprocesses. CRC Press, 2004.

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EN814: INDUSTRIAL HEALTH AND SAFETY

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Ability to provide industry with inputs on health and safety.
CO2: Internalize ISO 14001 and its implications for an industry.
CO3: Learn and disseminate issues related to occupational health and hazards.
CO4: Protocol development for an industry on disaster prevention, health issues, safety measures and environment management.

Course Content:

- Generate material, courses for workers and sensitization of industry managers.
- Be able to design and help recognition of an industry for IS014001.
- Work out measures for an industrial campus on all situations that could lead to a disaster, or a gradual degradation of the environment.
- Test and monitor industrial health and safety of an industry, and suggest remedies to fill gaps in implementation.
- Strategic management and planning and tools for implementing health and safety measures.
- Management of communicable diseases.
- Principles of accident prevention.
- Set up measures for altering organisational behaviour and risk management

Recommended Books:

- Reese C.D. (Occupational Health and Safety Management: A Practical Approach, Third Edition, CRC Press, 2017.
- Smedley J., Dick F., and Sadhra S. (Eds), Oxford Handbook of Occupational Health (2 ed.), Oxford University Press, 2013.
- Dentch M.P., The ISO 14001:2015 Implementation Handbook: Using the Process Approach to Build an Environmental Management System , ASQ, 2016.

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12. DETAILED SYLLABUS (SKILL ENHANCEMENT COURSES)

EN521: REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM AND MODELING

L4 T0 P0 CH4 CR4

Course Outcomes:

CO1: Building a foundation for understanding Remote Sensing and Geographic Information System (RS-GIS) as a powerful tool for geospatial analysis.
CO2: Build the foundation of understating of cartography, digital image, spatial and non-spatial data and geospatial terminology.
CO3: Learn about data and sources (RS based and other sources, field data collection) and integrate those into GIS environment for analysis.
CO4: Appreciate the application of RS-GIS techniques to the matrices of environment and Resource management.
CO5: Obtain Basic competence in skills with functional knowledge of the fundamentals to carry out GIS (RS-GIS) based project.

Course Content:

- Remote Sensing: definitions and principles; electromagnetic (EME) spectrum; interaction of EMR with Earth's surface; spectral signature; satellites and sensors; aerial photography and image interpretation.
- Geographical Information Systems: definitions and components; spatial and non-spatial data; raster and vector data; database generation; database management system; land use/ land cover mapping; overview of GIS software packages; GPS survey, data import, processing, and mapping.
- Applications and case studies of remote sensing and GIS in geosciences, water resource management, land use planning, forest resources, agriculture, marine and atmospheric studies.
- Basic elements of statistical analyses: sampling; types of distribution – normal, binomial, poisson; measurements of central tendency and dispersion; skewness; kurtosis; hypothesis testing; parametric and non-parametric tests; correlation and regression; curve fitting; analysis of variance; ordination.
- Hands-on: Based on the theory.

Recommended Books:

- Lillesand T. M., Remote Sensing and Image Interpretation. John Wiley, 7th Edition, 2015
- Burrough P.A. and McDonnell R.A., Principles of Geographical Information Systems. 2nd Edition, Oxford University Press, 2006.
- Jense J. R., Remote Sensing of the Environment – An earth resource perspective. Pearson Education, 2nd Edition, 2013

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EN522: ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

L4 T0 P0 CH4 CR4

Course Outcomes:

CO1: Explain the environment and its natural, and socio-economic and cultural components, and its temporal and spatial dimensions.
CO2: Comprehensively understand of the origin and development of EIA and the developments in India.
CO3: Appreciate the EIA process.
CO4: Define impact and identify, and predict impacts.
CO5: Understand the Indian EIA process and clearance regime and functional knowledge of environmental management plan (EMP), and environmental audit.

Course Content:

- Define Environment and its components, characteristics of Impact, and Projects and stages. Environmental impact assessment (EIA): definitions, introduction and concepts; rationale and historical development of EIA; Components and EIA.
- The EIA Process, scope and methodologies; role of project proponents, project developers and consultants; Terms of Reference; impact identification and prediction; baseline data collection; Public consultation in EIA.
- Environmental Impact Statement (EIS), Environmental Management Plan (EMP).
- EIA regulations in India; status of EIA in India; current issues in EIA; case study of hydropower projects/ thermal projects.
- Rapid EIA; Strategic Environmental Assessment; Social Impact Assessment; Biodiversity Impact Assessment; Cost-Benefit analysis; Life cycle assessment; environmental appraisal; environmental management - principles, problems and strategies; environmental planning; environmental audit.
- Risk assessment: introduction and scope; project planning; exposure assessment; toxicity assessment; hazard identification and assessment; risk characterization; risk communication; environmental monitoring; community involvement; legal and regulatory framework; human and ecological risk assessment.

Recommended Books:

- Barrow, C.J. Social Impact Assessment: An Introduction. Oxford University Press. 2000.
- Glasson, J., Therivel, R., Chadwick, A. Introduction to Environmental Impact Assessment. London, Research Press, UK. 1994.
- Judith, P. Handbook of Environmental Impact Assessment. Blackwell Science. 1999.
- Marriott, B. Environmental Impact Assessment: A Practical Guide. McGraw-Hill, New York, USA. 1997.
- The environment (Projection) Act 1986
- The Environmental Impact Assessment Notification, 1994, GoI
- Environmental Impact Assessment Notification, 2006

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13. DETAILED SYLLABUS (GENERAL ELECTIVE COURSES)

EN631: ENVIRONMENT AWARENESS

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: The students will learn the basic concepts and importance of environmental awareness.
CO2: They will also learn about the environmental priorities and the crisis in India, role played by the government, NGOs and media to promote and enhance the environmental awareness in the public.
CO3: Besides, they will also learn about various environmental movements and activities of national/international organizations to conserve the environment.

Course Content:

- Man and environment: Human activities and its impacts- local, regional and global; short-term and long-term impacts on environment; Socio-economic and cultural dimensions of environment, Concepts of carrying capacity and global commons; Environmental priorities in India and Environmental crisis.
- Environmental Awareness: definitions and concepts, role of Government, NGOs and media, Biosphere and socioeconomic and cultural environment and their interactions; Environment awareness programme in Northeast India with special emphasis on Manipur.
- Natural Resources and Conservation, Ecological security, Common property Resources (CPR), Environmental movements in India-Chipko, Apiko, Silent Valley, Tehri Dam, Narmada Dam.
- National and international organizations involved in environmental conservation and campaigns- Green Peace, WWF, WHO, IUCN, FAO, UNEP and UNESCO; Conventions and Summits on Environment; Carbon trading and sequestration, Clean Development Mechanism (CDM), Kyoto protocol.

Recommended Books:

- Meenakshi, P. (2005) Elements of Environmental Engineering. Eastern Economy Edition, Prentice Hall, India.
- Patil, R.B. (2009) Environment in Indian Society- Problem and Prospects. Mittal Publications, Daryaganj, New Delhi.
- Ramakrishnan, P.S. (2002) Sustainable Development. UNESCO, New Delhi.
- Senapati, T. and Sahoo, R.K. (2009) Environmental Education and Pollution Control. Mittal Publications, Daryaganj, New Delhi.
- Thomas A. et al. (1995) Trading with the Environment Ecology: Economics, Institutions and Policy. Earthscan, UK.
- Uberoi, N.K. (2004) Environmental Management. Excel Books, New Delhi.
- Vij J. Nornam and Axelrod (1999) The Global Environment, Institutions, Law and Policy. Earthscan Publishers Ltd, UK.

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EN632: GREEN TECHNOLOGIES

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Knowledge on importance and significance of green technology.
CO2: Knowledge on development and application of innovative technologies in conversion natural forms energy to economically and environmentally feasible forms.
CO3: Ability to develop, fabricate and utilize eco-friendly and cost-effective products in a variety of applications, and green design in building and infrastructure.
CO4: Ability to understand the role of green technology in resource generation, employment and improvement of livelihood standards.
CO5: Knowledge of various environmental monitoring and assessment tools, and industrial safety and hazard analysis.

Course Content:

- Introduction: History, concept and current scenario of green technology; green technology and sustainability.
- Development and application of innovative technologies in conversion natural forms of energy such as hydro-energy, solar energy, wind energy, tidal energy and geo-thermal energy to economically and environmentally feasible forms.
- Development, fabrication and various applications of eco-friendly biosensors, nano materials, biopolymers, biogas, bioethanol and biofuel.
- Development and application of eco-friendly and cost-effective tools in environmental pollution management and agricultural activities.
- Green design, building and infrastructure.
- Role of green technologies in resource generation, employment and improvement of livelihood standards.
- Life cycle assessment (LCA), life cycle costing (LCC), material flow analysis (MFA), cost benefit analysis (CBA), cost-effective analysis (CEA), carbon footprint, ecological footprint, and eco-labelling.
- Environmental management system (EMS), and industrial safety and hazard analysis.

Recommended Books:

- Bewick, M.W., Handbook of organic waste conversion. Van Nostr and Reinhold Co. 1980
- Rai, G.D., Non-conventional sources of energy. Khanna Publishers, 2013
- Kiang, Y.H., Waste energy utilization technology. United States, 1981.
- Sanghi, R. and Srivastava, M.M., Green Chemistry: Environment Friendly Alternatives. Alpha Science Int'l Ltd. 2003.
- Abele, E., Anderl, R. and Birkhofer, H., Environmentally-friendly product development. Springer-Verlag London Limited, 2005.
- Moss, T. and Marvin, S., Urban infrastructure in transition: networks, buildings and plans. Routledge, 2016.
- Green, L., Communication, technology and society. Sage, 2002.
- Murugesan, S., Harnessing green IT: Principles and practices. IT professional, 10(1), pp.24-33, 2008.
- Kumar, A., Bisht, B.S., Joshi, V.D. and Dhewa, T., Review on bioremediation of polluted environment: A management tool. International journal of environmental sciences, 1(6), p.1079, 2011.
- Soyez, K. and Plickert, S., Mechanical-biological pre-treatment of waste: State of the art and potentials of biotechnology. ActaBiotechnologica, 22(3-4), pp.271-284, 2002.
- Krass, D., Nedorezov, T. and Ovchinnikov, A., Environmental taxes and the choice of green technology. Production and operations management, 22(5), pp.1035-1055, 2013.
- Curran, M.A., Environmental life-cycle assessment. The International Journal of Life Cycle Assessment, 1(3), pp.179-179, 1996.
- Asiedu, Y. and Gu, P., Product life cycle cost analysis: state of the art review. International journal of production research, 36(4), pp.883-908, 1998.

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EN731: ENVIRONMENT AND SOCIETY

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Understand the human surrounding and the role of human being in shaping the surrounding.
CO2: Ability to understand the need to address current environmental issues.
CO3: Ability to draw conclusions form environmental movements, environmental legislations.
CO4: Knowledge on forest and environment, agriculture and environment, and institutional initiatives in the field of environment.
CO5: Knowledge on the role of Indian traditions and culture in environment and its priorities.

Course Content:

- Human beings and environment: Current environmental issues– pollution, trans boundary issues, biodiversity loss, climate change, urbanization, land degradation, Environmental issues of urban areas, solid wastes, e-wastes, hazardous wastes.
- Role of the society – interest groups, awareness and conservation, rights and duties, the constitutional provisions – Article 48A and Article 51A(g), environmental legislations, green benches, international cooperation, Economy of the environment, environmental good, Common property resources, the tragedy of commons.
- Environmentalism, Environmental movements – Chipko, Appiko, Narmada Bachao Andolan, Bishnoi movement.
- Issues with Indian agriculture – modern Vs organic agriculture, crop biodiversity Vs monoculture, energy and water availability, agro-marketing, farmers' wellbeing and subsistence.
- The Panchayati raj, participatory development, institutional initiatives for - resource development, sanitation and hygiene, social forestry, joint forest management, sacred groves.
- Environmental issues of Indian villages, biomass mass burning, exposure risk and gender, water availability, Water and gender, migration Indian traditions and conservation Indian environmental priorities.

Recommended Books:

- Poulopoulos, S. G., and Inglezakis V.J., Eds. Environment and Development: Basic Principles, Human Activities, and Environmental Implications. Elsevier, 2016.
- Harper, C. and Snowden M. Environment and society: Human perspectives on environmental issues. Routledge, 2017.
- Barr, S. Environment and society: Sustainability, policy and the citizen. Routledge, 2016.
- Schumacher, E. F. Small is beautiful: A study of economics as if people mattered. Random House, 2011.
- Hardin, G.. "The tragedy of the commons." science162.3859 (1968): 1243-1248.
- Carson, R.. "Silent spring. 1962." (2009).
- Agarwal, A. and Narain, S. eds. Dying Wisdom: Rise, fall and potential of India's traditional water harvesting systems. Centre for Science and Environment, 1997.

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EN732: FUNDAMENTALS OF ECOTOURISM

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Appricate concepts of ecotourism and its management.
CO2: Understand values of wildlife and minimizing impact on natural ecosystem due to tourism.
CO3: Learn basic concepts of ecotourism facility management and hospitality needs.
CO4: Appreciate sustainability in ecotourism.

Course Content:

- Introduction Ecotourism: concepts and definitions; Evolution and characteristics of ecotourism.
- Ecotourism guidelines: National and State level ecotourism guidelines; Laws, Tourism bill of rights; code for environmentally responsible tourism; World Ecotourism Summit.
- Tourism Impacts, Economic, social, political and environmental impacts, Sustainable Ecotourism – prospects and Challenges.
- Geography of India India's biodiversity, Parks and Sanctuaries, Environmental concerns.
- Community based Ecotourism, Significance of ecotourism planning Carrying capacity and development Benefits of sustainable tourism; Peoples' initiatives on Ecotourism, Community Education and Public Awareness (CEPA).
- Case study- ecotourism development in a hill station (existing infrastructural development and alternative measures to be suggested).

Recommended Books:

- Holden A. Environment and Tourism, Routledge, London, 2008.
- Sharma S.P., Tourism and Environment, Kanishka, New Delhi, 2006
- Weaver D. Eco-Tourism, John Wiley and sons Australia Ltd, 2008.
- Wood M., Eco Tourism – Principles, Practices and Policies for Sustainability, UNEP and TIES
- Beddard F.E., A text book of Zoogeography, BiblioLife

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EN831: FOLK CULTURES AND TRADITIONAL COMMUNITIES OF INDIA

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Appreciation of mega diversity of cultures.
CO2: Value of India's heterogenecity in diverse cultures and their uniqueness.
CO3: Importance of India's pluralistic, democratic and constitutional ethos.
CO4: Understanding folk traditions in agriculture, animal husbandry, fisheries, tribal foragers and their indigenous traditional knowledge systems (TKS).
CO5: Appreciation of maintenance of unique cultures in the vague of homogenization, globalization and urbanization.

Course Content:

- Diversity of traditional folk cultures.
- Lives and lifestyles of complex traditional communities.
- Linkage of biogeopgraphic zones to indigenous cultures.
- The "adivasi" their importance in futuristic India.
- Tribal art, handicraft, music, dance, folklore, mythology, dress codes, local food, etc.
- Communication, education and public awareness (CEPA) for long term preservation for traditional knowledge systems.
- Ethical issues in conservation of indigenous culture.

Recommended Books:

- Basham, A.L., The Wonder That was India, Surjeet Publications, 2008.
- Basham, A.L., The Illustrated Cultural History of India, OUP , 2007.
- Patra, A., The Spiritual Life and Culture of India, Oxford University Press, England. 2012.
- Henderson, C. E. Culture and Customs of India. Greenwood Publishing Group. 2002.
- Husnain, N., Tribal India, Palaka Prakashan, 2001.
- Husnain, N., Indian Society and Culture: Continuity and Change, 2010.
- Ministry of Tribal affairs, Government of India (https://tribal.nic.in/).

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EN832: ENVIRONMENTAL EDUCATION

L5 T1 P0 CH6 CR6

Course Outcomes:

CO1: Students will learn the impacts of human activities to the environment.
CO2: Will understand the concept of carrying capacity and ecological security.
CO3: Students will understand the environmental crisis in India and priorities to be focused.
CO4: They will be familiar with the concept of environmental education and its guiding principles; its current scenario in India and the world.

Course Content:

- Man and environment: Human activities and its impacts- local, regional and global; Concepts of carrying capacity and global commons; Ecological security, Common property Resources (CPR), Environmental priorities in India and Environmental crisis.
- Environmental education: Background and definition, Different approaches to EE, International norms guiding EE, Current scenario of EE in India and the world, Major challenges and the possible way-outs.
- Public awareness about environment: Need of creating public awareness about environment Role of individuals, NGOs and mass media. People involved in prominent environmental issues.
- Environmental ethics – concept, Eco-philosophy: eco-centric and anthropocentric world views, Environmental ethics and sustainable development; Imbibing lessons from religions, cultures and human values, Relevance of Environmental ethics in the present day society.

Recommended Books:

- Meenakshi, P. (2005).Elements of Environmental Engineering, Eastern Economy Edition, Prentice Hall, India.
- Patil, R.B. (2009). Environment in Indian Society- Problem and Prospects, Mittal Publications, Daryaganj, New Delhi.
- Ramakrishnan, P.S. (2002). Sustainable Development, UNESCO, New Delhi.
- Senapati, T. and Sahoo, R.K. (2009). Environmental Education and Pollution Control, Mittal Publications, Daryaganj, New Delhi.
- Thomas A. et al. (1995). Trading with the Environment Ecology: Economics, Institutions and Policy, Earthscan, UK.
- Uberoi, N.K. (2004). Environmental Management, Excel Books, New Delhi.
- Vij J. Nornam and Axelrod (1999). The Global Environment, Institutions, Law and Policy, Earthscan Publishers Ltd, UK.

15. SWAYAM COURSES

9.1 SWAYAM Courses: The University may allow up to 20% of the total courses. being offered in a particular program in a Semester through the online learning courses offered through SWAYAM platform subject to the following conditions:

1) The course contents are in compliance with the UGC (Credit Framework for Online Learning Courses through Study Webs of Active Learning for Young Aspiring Minds) Regulations, 2021 and its subsequent amendments;
2) The courses are not offered in the University/College.

9.2 The University shall give the equivalent credit weightage to the student for the credits earned vide online learning credit courses through SWAYAM platform, in the credit plan of the programme.

16. QUALIFICATION LEVELS AND CREDIT REQUIREMENTS

Following the UGC's nomenclature, qualification titles such as certificate, diploma and degree for the undergraduate programmes are organized in a series of levels inascending order as under:

Level 5: Bachelor's certificate;
Level 6: Bachelor's diploma;
Level 7: Bachelor's degree;
Level 8: Bachelor's degree with Honours.

The minimum credit requirements for these qualification types shall be as under:

(A) Bachelor's Certificate (Level 5)

Course (Credit)	Number	Course Credits	Minimum Credits
Core (6)	4	6x4=24	46
AECC (4)	2	4x2=8	
SEC (4)	2	4x2=8	
VAC (2)	3 (Minimum)	2x3=6 (Minimum)	

(B) Bachelor's Certificate (Level 6)

Course (Credit)	Number	Course Credits	Minimum Credits
Core (6)	10	6x10=60	96
GEC (6)	2	6x2=12	
AECC (4)	2	4x2=8	
SEC (4)	2	4x2=8	
VAC (2)	4 (Minimum)	2x4-8 (Minimum)	

(C) Bachelor's Certificate (Level 7)

Course (Credit)	Number	Course Credits	Minimum Credits
Core (6)	14	6x14=84	140
DSE (6)	2	6x2=12	
GEC (6)	3(Minimum)	6x3=18(Minimum)	
AECC (4)	2	4x2=8	
SEC (4)	2	4x2=8	
VAC (2)	5(Minimum)	2x5=10(Minimum)	

(D) Bachelor's (Hons.) Degree (Level 8)

Course (Credit)	Number	Course Credits	Minimum Credits
Core (6)	18	6x18=108	182
DSE (6)	4	6x4=24	
GEC (6)	4(Minimum)	6x4=24(Minimum)	
AECC (4)	2	4x2=8	
SEC (4)	2	4x2=8	
VAC (2)	5(Minimum)	2x5=10(Minimum)	

17. ASSESSMENT IMPLEMENTATION PLAN

Stage wise assessment plan will be adopted through a repetitive and systematic approach. The main purpose of planning the assessment process is to evaluate that methods of assessing the learners are suitable with respect to each program learning outcome. This will also help the respective faculty/school to analyze the performance of the students to the desired standards; to revise vis- à-vis refine the assessment criteria; and also to make necessary alterations in the programme in a liberal manner. It is also expected that the respective faculty would adopt rubrics as part of the appraisal process. The rubrics would define what is expected and what will be assessed, and would detail the criteria; creating a simpler, fairer, transparent, and yet accomplished grading and ranking system. Overall, the evaluation criteria will be established for each of the five student learning outcomes. A five-point rubric rating scales may be developed by the faculty/school/department as shown in the following example:

5 points = Exceeds expectations
4 points = Meeting expectations
3 points = Fairly competent
2 point = Approaching
1 point = Not there yet

Similar type of rubric scaling may be framed from the given structure encompassing the local factors and average student characteristics of the region or state.

18. MARKS DISTRIBUTION AND EVALUATION

Total marks for each course shall be based on internal assessment (25%) and semester end examination (75%). The internal assessment of 25% shall be distributed as under:

(i) Test/Assignment/Seminar/Field Work/Project Work/Case Study: 20%;
(ii) Attendance: 5%.

19. LETTER GRADE AND GRADE POINT

The 10-point grading system of the UGC, as described below, will be adopted for assessment and examination of the performance of students in various courses of the undergraduate programmes. **Letter Grade** is used to signify the level of qualitative/quantitative academic achievement of a student in a Course, while the Grade Point is used to indicate the numerical weight of the Letter Grade on a 10-point scale. Letter Grades 'O' to 'P' indicate successful completion of a Course, while Letter Grades 'F' and 'Ab' indicate 'fail' and 'Absent' respectively.

Table: Letter Grades and Grade Points:

Letter Grade	Grade Point	% of Marks	SGPA/CGPA	Description
O (Outstanding)	10	90-100	9.0-10.0	Outstanding
A+ [Excellent)	9	80-89	8.0 -8.9	First Class Exemplary
A (Very Good)	8	70-79	7.0-7.9	First Class Distinction
B+ (Good)	7	60-69	6.0-6.9	First Class
B (Above Average)	6	55-59	5.5-5.9	High Second Class
C(Average)	5	50-54	5.0-5.4	Second Class
P (Pass)	4	40-49	4.0-4.9	Pass
F (Fail)	0	00-39	0.0-3.9	Fail
Ab	0	---	---	Absent

20. ACCUMULATION OF CREDITS

Every student shall open an account in the Academic Bank of Credits which will provide him/her with a unique ID and will allow access to the Standard Operating Procedure (SOP). The Credits awarded to a student for the courses pursued in the University shall be accumulated in the Academic Bank Account of the student. The procedure for accumulation of credits earned, shelf life, redemption of credits, would be as per the UGC (Establishment and Operation of Academic Bank of Credits in Higher Education) Regulations, 2021 and their subsequent amendments. The validity of credits earned will be to a maximum period of seven years or as specified by the Academic Bank of Credits.

21. DURATION OF THE UNDERGRADUATE PROGRAMMES

Every student admitted to an undergraduate programme for a qualification (Level 5) to Level 8) shall be required to complete the programme within a period of 2 (two) years from the date of admission to the programme of each qualification level.

22. GRADUATE PROGRAMME LEARNING OUTCOMES ASSESSMENT MATRIX

Student Learning Outcomes: The expected ability of students after completion of the Undergraduate Programme in Environmental Science programme.	Assessment: How we will assess how well students are learning this.
Ability to recognize the need for learning the topic and develop foundational knowledge on the topic.	*Over a period of 4 years* Interview; Internal review; External review
Ability to develop critical thinking and problem solving skills to solve interdisciplinary issues related to the topic.	*Over a period of 4 years* Project/practical Interview; Interview; Internal review; External review
Ability to understand the relationships between natural and man-made systems.	*Over a period of 4 years* Writing skill; Presentation; Internal review External review
Ability to apply statistical methods, ICT and innovative techniques in classroom, field and laboratory to analyze scientific data.	*Over a period of 4 years* Writing skill; Presentation; Interview; Internal review; External review
Ability to develop lifelong learning and professional skills.	*Over a period of 4 years* Writing skill; Presentation; Interview; Internal review; External review
Ability to design and execute a scientific project, write scientific reports, develop research and communication skills.	*Over a period of 4 years* Writing skill; Presentation; Interview; Internal review External review
Ability to spread awareness about the environment around us, sustainable development and conduct outreach activities.	*Over a period of 4 years* Writing skill; Interview; Internal review; External review
Ability to gain empirical knowledge on the topic and contribute in decision making processes.	*Over a period of 4 years* Writing skill; Interview; Internal review; External review

23. TEACHING-LEARNING PROCESS FOR UNDERGRADUATE PROGRAMME IN ENVIRONMENTAL SCIENCE

It has been envisaged to impart of holistic knowledge and understanding of the various components of environmental Science and the interfaces and inter-linkages of all the aspects of local, regional, and global environment through the of Undergraduate Programme in Environmental Science programme. The learning process is expected to lead to the development of academic and professional skills necessary for professionals dealing with environmental issues in varied sectors – industry, academic, and government and non- government organizations. Development of critical thinking and decision making, empowered with skill, would be the key emphasis of teaching- learning for this programme. The approaches to teaching-learning process under this programme would include lectures, seminars, tutorials, workshops, field- based study, practical and project-based learning adequately substantiated with laboratory-based experiments, and industrial and field visits. The outcome- centric approach warrants promoting the transition from teacher-centric to learner-centric pedagogies. Adopted teaching strategies would encourage in developing problem-solving skills and higher-order skills of reasoning and analysis among the learners.

Teaching methods may include: lectures supported by group tutorial work; practical and field-based learning; utilization of prescribed textbooks and e-learning resources and other self- study materials; project work; and internship and visits to field sites, and industrial or other research facilities etc. The concerned faculty needs to stimulate the learning on a balanced apportionment of 30:30:40 norms. Here, lectures (listening/hearing) encompasses 30 percent of the delivery; audio-visuals (seeing/power point presentation/video/demonstrations) constitutes 30percent of the learning mechanisms; and practice (doing/participating/discussion) 40 percent. However, the given ratio may be altered according to the specific needs of the respective Institution/University. The teacher may also have the freedom to develop or evolve any other knowledge transfer method for achieving the basic goals of focused learning and holistic development. The following broad approaches are suggested for comprehensive outcome oriented and participative learning.

Lectures: Lectures may be schemed to offer the learners the up-to-date contexts on the subject matter, which is interactive and involving students in joining hands with their teachers to get new insights of the subject. The teacher may postulate the lecture outcomes in the beginning of the lectures and subsequently summarize the major aspects covered during the lecture at the end to keep the focus on the outcome.

Case Studies*:* As and when possible, case studies of real nature may be taken up to train the students in evolving creative solutions of multifaceted environmental problems faced by the society.

Field visits: Wherever there is scope, visit to nearby forest areas, gardens, agricultural lands, industrial units, industrial safety operational sites, urban green space, organic farming sites, water treatment plants, optional visits based on biogeographic locations (national parks, wildlife sanctuaries, zoos, mangroves for coastal areas, mountains),conservation based NGOs and research organization, interpretation centre, research laboratory , rehabilitation centre, SPCB (State Pollution Control Board) waste dumping sites, and factories may be undertaken and student may be asked to communicate findings of the field visit in the form of a report and seminar.

Laboratory Sessions: Laboratory sessions are important to train a student to follow specific procedures for obtaining scheduled outcome. This helps students gain confidence on the theoretical knowledge obtained from lectures and self-studies and adept them to handle equipment, learn standard techniques, collect and interpret data, and write reports. For the improvement of the lab experience of the students following should be implemented:

Simulations*:* Student may be given adequate hands on exposure to work some computational tools/software MATLAB, SPSS, Sigma-Plot, Sci lab, lab view, and GIS package(s) like QGIS.

Problem Solving*:* Apart from the standardized procedure given in laboratory manuals, student could be assigned with a scientific problem for encouraging them in formulating their own way to solve the given problem.

Laboratory Report: The Laboratory report should clearly reflect the student's experience and their understanding on the science behind the experiments. Report writing helps students to collate the ideas and findings. In general, a laboratory report may be systematically organized in various sections as *Introduction, Procedure, Results, and Conclusion/Interpretation* of the obtained results. The *Introduction* section would define the problem statement, establish scientific concept, and provide logical reasoning. *Results* must begin with effective statements of overall findings and results must be presented visually, clearly and accurately. The *conclusion* section must reflect the intrinsic values of the results.

Project-based learning:

Project-based learning offers an opportunity to the students to work independently under guidance of a supervisor. Students may be assigned to the respective faculty members under whose guidance he or she would work on a problem keeping the focus to enhance their (students') 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: Students may be allowed 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.

24. ASSESSMENT METHODS

Under the perspectives of the diversity in learning and pedagogical methods adopted by different universities and institutions, universities are expected to ensure that the assessment tools are satisfactorily rendering clear information about the attainment level of course outcomes and program outcomes for each and every student.

Assessment priorities*:* Institutions must prioritize formative assessments (in semester activities including tests done at the department or instructor level) rather than giving heavy and final weightage to summative assessments (end-semester). Progress of learners towards achieving learning outcomes may be assessed making creative use of the following, either independently or in combination:

- Time-constrained examinations (say 1-hour or 2-hour tests)
- Closed-book and open-book tests (if applicable)
- Problem based assignments/ term papers
- Quizzes
- Lab reports
- Individual/Team assignments
- Oral presentations, including seminar presentation
- Viva voce
- Peer and self-assessment etc.
- Any other pedagogic approaches as may be relevant keeping in view the learner's level, credit load and class size.

Weightage Distribution: In view of the need for more activity centric evaluation, more marks may be assigned for in-semester i.e. internal evaluation. The distribution of marks in in-semester and end-semester examination should preferably be in the ratio of 40:60.

End Semester Examination: The semester end examination must focus on evaluating the problem solving, critical thinking and skill abilities of the students. The scope and priorities may be decided on the basis of the learning outcomes of the respective courses.

(*Institutions are expected to encourage instructors to bring in innovative and flexible methods to guarantee the fullest realization of Learning Outcomes outlined in the document. All such instructional and assessment requirements must be clearly communicated to all stakeholders at the time of course registration. Any subsequent change or minor modification necessary for fuller realization of learning outcomes must be arranged with due notice and institutional arrangement at the relevant level. Freedom and accountability of the stakeholder are key attributes that determine the success of the Learning Outcomes framework. The excellence of institutions will be increasingly determined by Learning Outcomes rather than programme or course objectives. Hence it is necessary to innovate continually in learning and assessment in order to ensure meaningful and socially relevant learning (with transparent Learning Outcomes indices) rather than rote learning.*)

25. KEY WORDS

Environment, atmosphere, lithosphere, hydrosphere, biosphere, pollution, remediation, physicochemical processes, modeling.

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