काशी हिन्दू विश्वविद्यालय BANARAS HINDU UNIVERSITY

BANARAS HINDU UNIVERSITY

Masters Program in Environmental Sciences

MSc Environmental Sciences (Earth & Atmospheric Sciences)
MSc Environmental Sciences (Ecological Sciences)
MSc Environmental Sciences (Environmental Biotechnology)

Offered by

Faculty of Environment & Sustainable Development

Institute of Environment & Sustainable Development

Banaras Hindu University

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(A) M.Sc. Environmental Sciences (Earth & Atmospheric Sciences)

Code	Subject	Credits		
		Theory	Practical	Total
I SEMESTER				
ME101	Fundamentals of Earth System Science (FC)	2	1	3
ME102	Fundamentals of Ecological Sciences (FC)	2	1	3
ME103	Fundamentals of Environmental Biotechnology (FC)	2	1	3
Choice Based Credit System (CBCS) (SEC)		2	-	2
ME104	Fundamentals of Hydrology (CC)	2	1	3
ME105M	Environmental Laws& Policies (Minor) (GEC)	2	-	2
ME106M	Sustainability Science (Minor)(CC)	2	-	2
ME107M	Disaster Risk Management (Minor) (CC)	2	-	2
	Total credits	16	4	**20**
II SEMESTER				
ME201	Environmental Chemistry & Toxicology (CC)	2	1	3
ME202M	Environmental Issues & Challenges (Minor) (GEC)	2		2
ME203	Natural Resource Management (CC)	2	1	3
ME204	Remote Sensing & GIS (SEC)	2	1	3
Choice Based Credit System (CBCS) (GEC)		2	-	2
ME205	Atmospheric Chemistry &Physics (CC)	2	1	3
ME206M	Environmental Impact Assessment (Minor) (SEC)	2	-	2
ME207	Science Communication (Thematic Review & Presentation) (AEC)	-	1	1
ME208	Study Tour/Experiential Learning (CC)	-	2	2
	Total credits	14	7	**21**
III SEMESTER				
ME301	Statistical Methods (AEC)	2	1	3
ME302	Environmental Modelling (CC)	2	1	3
ME303	Global Climate Change (CC)	2	1	3
Any Four of the following (DSEC)		2×4	1×4	3×4
ME304	Water Pollution Management			
ME305	Air Pollution Management			
ME306	Environmental Meteorology			
ME307	Climate Dynamics			
ME308	Environmental Geochemistry			
ME309	Urban Environment			
ME310	Computer Programing			
ME311	Water Resource Management			
ME312	Environmental Instrumentation			
ME313	Glaciology			
ME314	Oceanography			
ME315	Radiation & Isotopes			
ME316	Geoinformatics			
	Total credits	14	7	**21**
IV SEMESTER				
ME401	Dissertation/Thesis work (CC)			**8**
ME402	Presentation (CC)			**2**
	Total credits			**10**
	Overall credits			**20 + 21+ 21 +10 = 72**

Note: Minimum credit requirement is 72. Two non-credit elective courses for value based and man making education are essential for successful completion of M.Sc. degree. **AEC**: Ability Enhancement Courses; **CC**: Core Courses; **FC**: Foundation Courses; **GEC**: Generic Elective Courses; **SEC**: Skill Enhancement Courses; CBCS: Choice Based Credit System

(B) M.Sc. Environmental Sciences (Ecological Sciences)

Code	Subject	Credits		
		Theory	Practical	Total
I SEMESTER				
ME101	Fundamentals of Earth System Science (FC)	2	1	3
ME102	Fundamentals of Ecological Sciences (FC)	2	1	3
ME103	Fundamentals of Environmental Biotechnology (FC)	2	1	3
Choice Based Credit System (CBCS) (SEC)		2	-	2
ME108	Evolutionary & Behavioural Ecology (CC)	2	1	3
ME105M	Environmental Laws& Policies (Minor) (GEC)	2	-	2
ME106M	Sustainability Science (Minor)(CC)	2	-	2
ME107M	Disaster Risk Management (Minor) (CC)	2	-	2
	Total credits	16	4	**20**
II SEMESTER				
ME201	Environmental Chemistry & Toxicology (CC)	2	1	3
ME202M	Environmental Issues & Challenges (Minor) (GEC)	2		2
ME203	Natural Resource Management (CC)	2	1	3
ME204	Remote Sensing & GIS (SEC)	2	1	3
Choice Based Credit System (CBCS) (GEC)		2	-	2
ME209	Conservation Biology (CC)	2	1	3
ME206M	Environmental Impact Assessment (Minor) (SEC)	2	-	2
ME207	Science Communication (Thematic Review & Presentation) (AEC)	-	1	1
ME208	Study Tour/Experiential Learning (CC)	-	2	2
	Total credits	14	7	**21**
III SEMESTER				
ME301	Statistical Methods (AEC)	2	1	3
ME317	Quantitative Ecology	2	1	3
ME318	Human Ecology (CC)	2	1	3
Any Four of the following (DSEC)		2×4	1×4	3×4
ME319	Forest Ecology			
ME320	Wetland Ecology			
ME321	Agroecology			
ME322	Urban Ecology			
ME323	Landscape Ecology			
ME324	Molecular Ecology			
ME325	Soil Ecology			
ME326	Restoration Ecology			
ME327	Ecological Modelling			
ME328	Biodiversity Management			
ME329	Global Change Ecology			
ME330	Industrial Ecology			
ME331	Ecological Economics			
	Total credits	14	7	**21**
IV SEMESTER				
401C	Dissertation/Thesis work (CC)			**8**
402C	Presentation (CC)			**2**
	Total credits			**10**
	Overall credits			**20 + 21+ 21 +10 = 72**

Note: Minimum credit requirement is 72. Two non-credit elective courses for value based and man making education are essential for successful completion of M.Sc. degree. **AEC**: Ability Enhancement Courses; **CC**: Core Courses; **FC**: Foundation Courses; **GEC**: Generic Elective Courses; **SEC**: Skill Enhancement Courses; CBCS: Choice Based Credit System

(C) M.Sc. Environmental Sciences (Environmental Biotechnology)

Code	Subject	Credits		
		Theory	Practical	Total
I SEMESTER				
ME101	Fundamentals of Earth System Science (FC)	2	1	3
ME102	Fundamentals of Ecological Sciences (FC)	2	1	3
ME103	Fundamentals of Environmental Biotechnology (FC)	2	1	3
Choice Based Credit System (CBCS) (SEC)		2		2
ME109	Biochemistry (CC)	2	1	3
ME105M	Environmental Laws& Policies (Minor) (GEC)	2	-	2
ME106M	Sustainability Science (Minor)(CC)	2	-	2
ME107M	Disaster Risk Management (Minor) (CC)	2	-	2
	Total credits	16	4	**20**
II SEMESTER				
ME201	Environmental Chemistry & Toxicology (CC)	2	1	3
ME202M	Environmental Issues & Challenges (Minor) (GEC)	2		2
ME203	Natural Resource Management (CC)	2	1	3
ME204	Remote Sensing & GIS (SEC)	2	1	3
Choice Based Credit System (CBCS) (GEC)		2	-	2
ME210	Microbiology (CC)	2	1	3
ME206M	Environmental Impact Assessment (Minor) (SEC)	2	-	2
ME207	Science Communication (Thematic Review & Presentation) (AEC)	-	1	1
ME208	Study Tour/Experiential Learning (CC)	-	2	2
	Total credits	14	7	**21**
III SEMESTER				
ME301	Statistical Methods (AEC)	2	1	3
ME332	Molecular Biology & Genetic Engineering (CC)	2	1	3
ME333	Advanced Biotechnological Tools and Bioinformatics (CC)	2	1	3
Any Four of the following (DSEC)		2×4	1×4	3×4
ME334	Animal Biotechnology			
ME335	Bioresource Technology &Environmental Engineering			
ME336	Biosafety, IPR & Entrepreneurship			
ME337	Food Technology			
ME338	Genomics & Proteomics			
ME339	Industrial Biotechnology			
ME340	Nanobiotechnology			
ME341	Plant Biotechnology			
ME342	Immunology			
	Total credits	14	7	**21**
IV SEMESTER				
ME401	Dissertation/Thesis work (CC)			**8**
ME402	Presentation (CC)			**2**
	Total credits			**10**
	Overall credits			**20 + 21+ 21 +10 = 72**

Note: Minimum credit requirement is 70. Two non-credit elective courses for value based and man making education are essential for successful completion of M.Sc. degree. **AEC**: Ability Enhancement Courses; **CC**: Core Courses; **FC**: Foundation Courses; **GEC**: Generic Elective Courses; **SEC**: Skill Enhancement Courses; CBCS: Choice Based Credit System

(A) M.Sc. Environmental Sciences (Earth & Atmospheric Sciences)

FIRST SEMESTER

ME101.FUNDAMENTALS OF EARTH SYSTEM SCIENCE (2 Credits)

1. **The Earth and the solar system:** The solar system; Kepler's laws of planetary motion; Geological Time Scale; Age of the Earth; Basic principles of stratigraphy; Earth's gravity and thermal structure: geoid, spheroid; Isostasy

2. **Evolution of the Earth:** Modern theories on the origin of the Earth and other planetary bodies; Evolution of earth's atmosphere and oceans; Theories about the origin of life and the nature of fossil record: Earth's interior; Continental drift; Plate tectonics: mountain building; Volcanism; Earthquakes and Tsunamis

3. **Lithosphere:** Gross composition and physical properties of important minerals and rocks: properties and processes responsible for mineral concentrations; Nature and distribution of rocks and minerals in the earth and different parts of India; Genesis, classification and distribution of soils

4. **Atmosphere:** Vertical structure of atmosphere; Lapse rate, stability; Energy flow: conduction, convection, sensible and latent heat; Energy balance: radiation, absorption, scattering; Greenhouse gases and global warming; Radiative forcing, atmospheric boundary layer, dispersion of pollutants

5. **Hydro and cryosphere:** Cryosphere; Fresh water and marine ecosystem; Oceanic heat and salinity balance; Ocean currents; Marine food and economic resources; Biological productivity of the oceans

6. **Atmospheric physics and chemistry:** Sources of trace gases and particulates in the atmosphere; Key processes in atmospheric chemistry: oxidation chemistry, halogen chemistry; Properties of aerosols, role and measurements; Ozone depletion; Clouds formation, cloud microphysical processes; Artificial rainmaking

7. **Earth's climate:** Classification of climate: Koppen's and Thornthwaite's scheme of classification; Ocean and climate; Atmosperic and ocean circulation; Genesis and characteristics of ENSO, El-Nino, ENSO and Indian monsoon; Climate modelling; Climate change and its impact; Climate change policy

8. **Case studies:** Case studies and success stories

Suggested Readings

1. CN Hewitt, AV Jackson (2009) Atmospheric Science for Environmental Scientists. Blackwell
2. JH Seinfeld, SN Pandis (2016) Atmospheric Chemistry and Physics. Wiley
3. SE Manahan (2010) Environmental Chemistry. Wiley
4. SE Cornell, IC Prentice, JI House, CJ Downy (2012). Understanding the Earth System - Global Change Science for Application. Cambridge
5. J Marshall, RA Plumb (2008). Atmosphere, Ocean and Climate Dynamics: An introductory Text. Elsevier.
6. BJ Skinner, SC Porter, DB Botkin (2011). The Blue Planet: An Introduction to Earth System Science. Willey

ME101P. PRACTICALS BASED ON ME101 (1 Credit)

ME102. FUNDAMENTALS OF ECOLOGICAL SCIENCES (2 Credits)

1. **The scope of ecology:** The science of ecology; Historical development of ecological thoughts; Organization levels of ecological systems; Linking ecology and environmental issues

2. **The environment:** Biotic and abiotic environment and its interactions; Concept of limiting factors; Ecological adaptations; Habitat and niche concept

3. **Population ecology:** Population characteristics; Metapopulations; Population growth models; Concept of biotic potential and carrying capacity; Life history models (*r*&*K* selection); Factors regulating population growth

4. **Community ecology:** Nature of communities; Community interactions; Community structure and attributes; Species diversity and dominance

5. **Ecosystem ecology:** Ecosystem structure; Energy flow; Trophic levels; Food chains; Ecological pyramids; Ecological efficiencies; Trophic cascades; Ecosystem production, decomposition, Biogeochemical cycle of C, N and P; Nutrient cycling at ecosystem level

6. **Ecological succession:** Types; Mechanisms; Concept of climax; Steady state and stability in ecological systems; Ecosystem trends during succession

7. **Biogeography:** General features of major terrestrial and aquatic biomes; Theory of island biogeography; Biogeographical zones of India; Forest and grassland types of India

8. **Case studies:** Current case studies related to ecology; Dry tropical forests of India; Ecology of River Ganga

Suggested Readings

1. Odum EP, Barrett GW (2004) Fundamentals of Ecology (5th ed.). Brooks/ Cole Publishers
2. Krebs C (2009) Ecology: the experimental analysis of distribution and abundance (6th ed.). Pearson Benjamin Cummings, San Francisco.
3. Jørgensen SE (2010) Global Ecology (1st ed.) Academic Press
4. Stiling PD (2011) Ecology: Global Insights and Investigations. McGraw-Hill Education
5. Begon M, Howarth RW, Townsend CR (2014) Essentials of Ecology (4th ed.). Wiley
6. Velland M (2016**)** The Theory of Ecological Communities (MPB-57) (Monographs in Population Biology). Princeton University Press
7. Lawrence F (2017) Ecosystem Functioning & Restoration. Callisto Reference

ME102P: PRASCTICALS BASED ON ME102 (I Credit)

ME103. FUNDAMENTALS OF ENVIRONMENTAL BIOTECHNOLOGY (2 Credits)

1. **Introduction to biotechnology:** Historical Perspectives; Modern and old biotechnology; Biotechnology an interdisciplinary pursuit; Scope and future of environmental biotechnology

2. **Systems of molecular biology**: General organization of genetic material in prokaryotes and eukaryotes; Replication of genetic material; Gene and genetic code, transcription and translation, protein synthesis

3. **Techniques in biotechnology:** Biotechnology and its tools; Isolation and purification of genomic and plasmid DNA, RNA and protein; Electrophoresis; Polymerase chain reaction (PCR); Recombinant DNA techniques

4. **Basics of omics:** Concept and methods of genome, proteome, trancriptome and metabolome

5. **Basics of bioinformatics:** Application of information technology in biotechnology

6. **Biotechnology in environment:** Waste water and sewage treatment; Biofuels; Bioremediation: bioaugumentation, biotransformation, bioaccumulation; Biofertilizers; Biopesticides; Biological control in food security and biosafety

7. **Biotechnology in medicine:** Antibiotics; Vaccines; Gene therapy; Bio-pharmaceuticals; Bioreactors

8. **Case Study:** Classical and emerging issues of environmental biotechnology

Suggested Readings

1. Young MM (2011) Comprehensive Biotechnology. Second edition, Elsevier
2. Evans G, Furlong JC (2010) Environmental biotechnology: Theory and application. Oxford: Wiley-Blackwell
3. Fulekar MH (2010) Environmental biotechnology. Science Publishers
4. Jordening HJ, Winter J (2005) Environmental biotechnology: Concepts and applications. Wiley-VCH
5. Rittmann BE, McCarty PL (2001) Environmental biotechnology: Principles and applications. McGraw-Hill
6. Scragg AH (2005) Environmental biotechnology. Oxford University Press
7. Vallero D (2010) Environmental Biotechnology: A Biosystems Approach. Elsevier

ME103P. PRACTICALS BASED ON ME103 (1 Credit)

ANY ONE PAPER AS PER THE CHOICE BASED CREDIT SYSTEM (2 Credits)

ME105. FUNDAMENTALS OF HYDROLOGY (2 Credits)

1. **The Introduction to hydrology:** Definition and scope of hydrology; Hydrological cycle, Origin of groundwater, Subsurface distribution of water; Springs; Movement of water in plants

2. **Hydrological properties of water bearing materials:** Porosity; Void ratio; Permeability; Transmissivity; Storability by discharging methods; Specific yield; Specific retention; Diffusivity; Laboratory methods of determination of permeability

3. **Precipitation and its constituents:** Condensation and Precipitation; Space-time characteristics of precipitation and its analysis; Evaporation and its different methods of estimation; Transpiration; Evapotranspiration and its different methods of estimation; Consumptive use; Seepage; Infiltration and its measurements; Runoff

4. **Groundwater flow:** Water retention in soil; Water movement in saturated and unsaturated soils; Movement of groundwater and aquifer performance tests; Darcy's law and its range of validity; Theory of groundwater flow under steady and unsteady conditions

5. **Water resource management:** Planning and development; System design by operational research; Natural and artificial recharge of groundwater; Water balance; Analysis of hydrograph; Conjunctive and consumptive use of groundwater

6. **Quality of water:** Properties of water; Water quality determination; Water quality characteristics of surface and groundwater; Water pollution; Water quality requirement for specific use; Classification of groundwater in respect to domestic, irrigation and industrial use

7. **Hydrological Model:** Conceptual Model; Statistical models; Mathematical Model; Geographic Data Model; SWAT model, MODFLOW model; Model calibration and evaluation

8. **Case Studies:** Relevant case studies in environmental hydrology

Suggested Readings

1. Todd DK, Mays LW (2004) Groundwater Hydrology, Wiley
2. Ward R, Robinson M (2004) Principles of Hydrology, CRC press
3. Chow VT(2010) Handbook of Applied Hydrology, Tata McGraw-Hill Education
4. Eslamian S (2014) Handbook of Engineering Hydrology, CRC press
5. C W Fetter (2001) Applied Hydrogeology, Pearson

ME105P. PRACTICALS BASED ON ME105 (1 Credit)

ME106M. ENVIRONMENTAL LAW & POLICIES (MINOR) (2 Credits)

1. **Environmental protection in India**: Historical and modern mechanisms for environmental protection in India; Rules and regulations of central and state Government for environmental protection; Common law remedies

2. **National policy on environment:** National Committee on Environment and Planning (NCEP); National forest policy; National water policy; National energy policy; National wetland policy

3. **Constitutional provisions for environmental protection:** Constitutional provisions for environmental protections: fundamental duties of citizen and directive principles of state policy; Writ provisions for the protection of environment

4. **National environmental acts:** The Water (Prevention and Control of Pollution) Act, 1974; The Air (Prevention and Control of Pollution) Act, 1981; The Environment (Protection) Act, 1986; Mining Act, 1952; Factories Act; Motor Vehicle Act; Hazardous Waste legislation for pollution abatement; Hospital Waste Management

5. **National legislations on forest and wildlife:** The Forest (conservation) Act, 1980; The Wildlife (Protection) Act, 1972; The Biological Diversity (Protection) Act, 2002: aims, objectives and major contents; The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006

6. **Environmental legislations related to coastal zones:** Ambit and applicability of coastal regulation zone (CRZ) rules; Marine protected areas

7. **Institutional mechanisms for environmental protection:** Jurisdiction of High Courts, Supreme Court and Green Tribunal; Public interest litigation (PIL); Duties and functions of MoEF & CC; CPCB and SPCBs; NGT

8. **International environmental laws and treaties:** International agreements, conventions, treaties related to environment and sustainable development; Environmental quality and transboundary issues; Role of international agencies on environmental protection

Suggested Reading

1. Salzman J, Thompson Jr. B (2017) Environmental Law and Policy (Concepts and Insights) 3rd Edition, Foundation Press
2. Doabia TS (2017) Environmental and Pollution Laws in India, Vol I, LexisNexis
3. Doabia TS (2017) Environmental and Pollution Laws in India, Vol II, LexisNexis
4. Reddy KV (2013) Environmental Law, Asia Law House
5. Naseem M, Naseem S (2014) Environmental Laws in India (2nd Edition), Wolters Kluwer Law & Business

ME107M. SUSTAINABILITY SCIENCE (MINOR) (2 Credits)

1. **Foundations & history:** The emergence of sustainable development: its formative ideas and roots in development and environment debates; Key concepts and principles; The system dynamics of a finite planet; Basic thermodynamic and material laws and principles; Resource scarcity and carrying capacities

2. **Environmental justice:** The problem of allocation in the context of limits; The concept of environmental space and environmental inequality; Inter- and intra-generational justice; Contraction and convergence; Human rights to a safe environment

3. **Sustainable materials, technology and design:** The transformation of production process, infrastructures and systems; Concepts of resource efficiency, dematerialization, decoupling, clean or sustainable technologies, design for the environment, design for sustainability; Industrial ecology; Life cycle analysis

4. **Consumption, lifestyle & communication:** Getting to grips with the complexity of consumption and lifestyle; understanding people's motivations, attitudes, values and behaviours; The dynamics of transition and social change; The importance of gender issues in sustainable development

5. **Governance for sustainability:** Basic framing of the problem of governing common pool resources; history of governance, the social contract, 'governmentality'; Policy responses to sustainability; Agenda 21, UN SDGs

6. **The good life, development & wellbeing:** Wellbeing, quality of life and sustainability; sustainability as capabilities for flourishing within ecological limits; Philosophical and ethical dimensions of sustainable development

7. **Measuring sustainability:** Sustainability indicators; Research methods and reporting: tools, statistics and accounting

8. **Case studies:**Current case studies related to sustainability science

Suggested Readings

1. Daly HE (1996) Beyond Growth: the Economics of Sustainable Development. Beacon Press

2. Daly HE, Farley J (2010) Ecological Economics: Principles and Applications. Island Press
3. Elliott JA (2006) An Introduction to Sustainable Development. Routledge
4. Roosa SA (2010) Sustainable Development Handbook, Second Edition. Fairmont Press
5. Strange T, Bayley A (2008) Sustainable Development: Linking Economy, Society, Environment. OECD
6. Heinrichs H, Martens P, Michelsen G, Wiek A. (2015) Sustainability Science: An Introduction. Springer
7. Filho WL (2017) Handbook of Sustainability Science and Research. Springer
8. Dedeurwaerdere T (2014) Sustainability Science for Strong Sustainability. Elgar Publishing

ME108M. DISASTER RISK MANAGEMENT (MINOR) (2 Credits)

1. **Introduction and overview:** Understanding the concepts and definitions of hazard, disaster, and vulnerability; Risk: types, trends, causes and consequences of disasters; Disaster profile of India.

2. **Institutional framework, policy and guidelines:** Evolution of disaster management in India; Organisation and structure of disaster management in India; National policy on disaster management; National plan on disaster management.

3. **Prevention and mitigation**: Prevention and mitigation; Mainstreaming of disaster risk reduction in developmental strategy; National disaster mitigation fund

4. **Preparedness and response:**Disaster management cycle; Institutional arrangements; Crisis management plan and standard operating procedures; Role of Central and State Governments, National Emergency Operation Centre; National and State Disaster Response Force

5. **Recovery, reconstruction and rehabilitation:** Nature of recovery; Guiding principles for post-recovery, assessment, sustainability in recovery process; Guidance notes on recovery

6. **Capacity development, financial arrangements and international cooperation**: National institutions and disaster management centres in the States; Financing the relief expenditure;Hyogo Framework of Action; Agencies of United Nations involved in disaster management

7. **Application of Science and Technology**: Use of Remote Sensing, GIS and GPS; Early warning and disaster communication; Land use planning; Nature based solutions

8. **Case Studies**: Mega disasters of India and other parts of world.

Suggested Readings

1. MHA(2011) Disaster Management in India, Ministry of Home Affairs (MHA) Govt. of India, New Delhi
2. Srivastava HN, Gupta GD (2006) Management of Natural Disasters in developing countries,Daya Publishers, Delhi
3. Phillips, B (2009) Disaster Recovery. CRC Press
4. Oosterom V et al (2015) Geo-information for Disaster Management, Springer
5. Coppola DP (2015) Introduction to International Disaster Management, 3rd Edition, Elsevier

SECOND SEMESTER

ME201. ENVIRONMENTAL CHEMISTRY & TOXICOLOGY (2 Credits)

1. **Introduction to environmental Chemistry:** Fundamentals of Environmental Chemistry; Scope and future prospects; Tools and techniques in Environmental Chemistry

2. **Chemistry of air:** Physical and chemical properties; Air pollution: sources, sinks of air pollutants and management

3. **Chemistry of water:** Physical and chemical properties; Water pollution: sources, sinks of water pollutants and management

4. **Chemistry of soil:** Physical and chemical properties; Soil pollution: sources, sinks of soil pollutants and management

5. **Toxicity testing and dose response relationship:** Principles and Standards of toxicity testing; Methods in toxicity evaluation at genetic, cellular and molecular level by *in-vivo* and *in-vitro* methods; Dose-response relationship; Detoxification mechanisms in plants, animals and human beings

6. **Toxicity of xenobiotics**: Cellular, molecular and biochemical effects of xenobiotics including persistent organic pollutants (POPs) in living organisms; Remedial measures for reducing POPs toxicity

7. **Toxicology of microbial toxins:** Microbial toxins in environment; Cellular, molecular and biochemical effects of microbial toxins in humans and animals; Food poisoning and control measures

8. **Case studies:** Minamata disease in Japan; Bhopal disaster; Endosulfan pollution in Kerala; Arsenic poisoning in Indo-Gangetic plain and other emerging ecotoxicological issues

Suggested Readings

1. Vanloon GW, Duffy SJ (2010) Environmental Chemistry: a global perspective. Oxford University Press
2. De AK (2000) Environmental Chemistry, 4thedition. New age International (P) Ltd
3. Johnson DO, Netterville JT, Wood JC, James M (1973) Chemistry and the Environment.W.B. Saunders Company
4. Lave LB,Upton AC (1987) Toxic Chemicals, health and the Environment. The Hopkins Press Ltd
5. Manhan (2000) Environmental Chemistry, 7thedition. CRC Press.
6. Midoand Y, Satake M (2003) Chemicals in the environment. Discovery Publishing House

ME201P. PRACTICALS BASED ON ME201 (1 Credit)

ME202M. ENVIRONMENTAL ISUES & CHALLENGES (MINOR) (2 Credits)

1. **Man and environment:** Impact of human population on environment; Ethical issues regarding unscientific development and environmental degradation; Impact of global land cover and land use change; Causes, effects and mitigation strategies for global climate change and stratospheric ozone loss

2. **Environmental pollution:** Causes and effects of air, water, soil, noise, radioactive pollution; Basic pollution abatement practices and technologies

3. **Biotic invasions:** Extent and mechanisms of biological invasions; Ecological and economic impacts; Management strategies

4. **Loss of biodiversity** : Threats and pattern of biodiversity loss; Natural and anthropogenic causes; IUCN threat categories, Red data books; Conservation and restoration of biodiversity

5. **Global water crisis:** Distribution, withdrawal and consumption patterns; Causes and effects of water crisis; Water conservation approaches

6. **Global energy crisis:** Sources of energy supply; Current potential and future prospects of energy sources; Energy crisis; Energy conservation strategies

7. **Challenges of urbanization:** Recent trends of urbanization; Environmental impact of urbanization; Concept of green cities

8. **National policies and action plan on environment:** National Forest Policy; National Water Policy; National Energy Policy; National Action Plan on Climate Change; National Biodiversity Action Plan; Carbon crediting; Green taxes; Clean development Mechanisms

Suggested Readings

1. McConnell R (2008) Environmental issues: An introduction to sustainability. Pearson
2. Wali MK., Evrendilek F, Fennessy M (2009) The environment: science: Issues and solutions. CRC Press
3. Neelin J (2011) Climate change and climate modelling. Cambridge University Press
4. John Marshall R, Plumb A (2008) Atmosphere, ocean and climate dynamics: An introductory text. Elsevier
5. Phillips B, Thomas D, Fothergill A, Blinn-Pike L (2009) Social vulnerability to disasters. CRC Press
6. Hill M (2010) Understanding environmental pollution. Cambridge University Press
7. Morin FJ, Orsini A (2015) Essential Concepts of Global Environmental Governance. Routledge
8. Vig NJ, Kraft ME (2015) Environmental Policy: New Directions for the Twenty-First Century, (9th ed.). CQ Press

ME203. NATURAL RESOURCE MANAGEMENT (2 Credits)

1. **Introduction:** Types of natural resources, their consumption patterns; Human population explosion and resource degradation and conservation; Factors influencing resource availability, distribution and uses; Ecological, social and economic dimension of resource management

2. **Land resources:** Current status of national and global land resources; Land degradation: natural and anthropogenic drivers; Sustainable strategies for land resource management; Role of indigenous and local knowledge (ILK) in land resource management

3. **Water resources:** Current status of national and global water resources; Water pollution; Sustainable strategies for land resource management; Integrated watershed management; Role of indigenous and local knowledge (ILK) in water resource management

4. **Forest resources:** Current status of national and global forest resources; Forest degradation: natural and anthropogenic drivers; Sustainable strategies for forest resource management; Role of indigenous and local knowledge (ILK) in forest resource management

5. **Marine resources**: Current status of global marine resources; Marine pollution: natural and anthropogenic drivers; Sustainable strategies for marine resource management

6. **Minerals resources**: Current status of mineral resources in India; Environmental impact of mineral exploitation; Sustainable strategies for mineral resources management

7. **Energy resources:** Current status of conventional and non-conventional energy sources; Environmental impacts of energy exploitation; Cleaner and alternative sources of energy; Sustainable strategies for energy resources management

8. **Case Studies:** Current case studies related to natural resource management in India

Suggested Readings

1. Singh JS, Gupta SR, Singh SP(2014) Ecology Environmental Science and Conservation, Chand Publishing
2. Pandey BW (2005) Natural Resource Management, Mittal Publications
3. Morin FJ, Orsini A (2015) Essential Concepts of Global Environmental Governance. Routledge, ISBN 978-0-41582-247-3
4. Anderson DA (2013) Environmental Economics and Natural Resource Management, Routledge
5. Knight RL, Bates SF (1995) A New Century for Natural Resources Management, Island Press
6. Chiras DD, Reganold JP (2013) Natural Resource Conservation: Pearson New International Edition: Cases and Moral Reasoning, Pearson Education Limited

ME203P. PRACTICALS BASED ON ME203 (1 Credit)

ME204. REMOTE SENSING & GIS (2 Credits)

1. **Basics of remote sensing:** Background and history of remote sensing; Fundamentals of remote sensing: electromagnetic radiation, energy matter interaction; Platforms and sensors; Characteristics of images; Optical and microwave satellites

2. **Digital image processing:** Digital image data formats; Image rectification and restoration techniques: geometric correction, radiometric correction and noise suppression, image histograms, density slicing; Image enhancement techniques: contrast manipulation, spatial filtering and edge enhancement, atmospheric correction of satellite images

3. **Geographic Information Systems:** Fundamentals of GIS, vector, raster and attribute data models, vector and raster data structure; Spatial data input and editing; Visualization and query of spatial data; Spatial data transformations, spatial analysis

4. **Multi-image manipulations:** Spectral rationing, vegetation indices; Principal components analysis; Multi and hyper-spectral image classification; Supervised and unsupervised algorithms; Object based classification

5. **Microwave remote sensing:** Introduction to microwave remote sensing; Radar and radiometer, radiative transfer; Microwave missions and products definitions

6. **Hyperspectral remote sensing:** Introduction to hyperspectral remote sensing, hyperspectral radiometer; Hyperspectral missions and products definitions

7. **Global navigational satellite system:** Basics of GNSS; Concept of global positioning system (GPS), working of GPS, types of GPS; Differential GPS; Future GPS and applications of GPS

8. **Case studies:** RS and GIS applications in air quality modelling, early warning, urban planning, biodiversity and forest mapping, snow cover simulation, ocean salinity, disaster management.

Suggested Readings

1. Islam T, Alexander YH, Wang KJ (2018) Remote Sensing of Aerosols, Clouds, and Precipitation. Elsevier
2. Burrows JP, Platt U, Borell P (2014) The Remote Sensing of Tropospheric Composition from Space. Springer
3. Kokhanovsky AK, Leeuw GD (2013) Satellite aerosol remote sensing over land. Springer
4. Joseph G (2009). Fundamentals of Remote Sensing. University Press
5. Huisman O, de RA (ed.) Principles of Geographic Information Systems, Fourth edition. ITC Educational Textbook Series. ITC, Enschede, The Netherlands

ME204P. PRACTICALS BASED ON ME204 (1 Credit)

ANY ONE PAPER AS PER THE CHOICE BASED CREDIT SYSTEM (2 Credits)

ME205: ATMOSPHERIC CHEMISTRY & PHYSICS (2 Credits)

1. **The Atmosphere:** Introduction to evolution and composition of earth's atmosphere; Atmospheric profiles: pressure, temperature and density; Different unit systems and their application in atmospheric sciences; Chemical and dynamical lifetime of atmospheric constituents; Concept of residence times; Box models and transport scales
2. **Thermodynamics of atmosphere:** Thermodynamic principles; Atmospheric moisture; Classification and vertical structure of the atmosphere; Thermodynamics of dry and moist air, lapse rate, hydrostatic equation, thermodynamic diagrams, potential temperature, stability; Thermodynamics of water
3. **Radiation:** Radiation in the atmosphere; Earth's energy balance, Radiative equilibrium, Quantitative description of radiation; Basic radiation laws-The Plank Function-Wiens displacement Law-The Stefan-Boltzmann Law; Radiative properties of non-black materials-Kirchoff's Law
4. **Chemistry of Troposphere:** Tropospheric chemistry of reactive gases, sources and inventories; Oxidation-reduction reactions; Oxidizing capacity of the atmosphere; Heterogeneous and homogenous chemical reactions and processes; Atmospheric photochemical reactions; Atmospheric effects- pollution, air quality, fog, smog, visibility, acid rain and precipitation chemistry
5. **Chemistry of stratosphere:** Stratospheric and atmospheric ozone chemistry; Evolution of ozone layer: UV radiation, Chapman mechanisms, Chloroflurocarbons, Polar ozone loss and recovery of stratospheric ozone; Stratospheric-tropospheric exchange
6. **Aerosols:** Atmospheric aerosols: source, sinks, removal mechanism; Size distribution, carbonaceous aerosols; Black carbon, brown carbon; SOA formations: chemistry and mechanisms; radiative impact of aerosols

7. **Cloud physics:** Properties of water and water solutions; Water equilibrium in the atmosphere; Cloud and fog formation; Cloud microphysical processes, condensation nuclei, growth rate of individual cloud droplets; Cloud processing of aerosols; Aerosol-cloud-climate interaction.
8. **Case studies:** Case studies related to atmospheric physics & chemistry

Suggested readings:

1. JH Seinfeld and SN Pandis (2016). Atmospheric Chemistry and Physics. Wiley.
2. RM Harrison (2007). Principles of Environmental Chemistry. RSC Publishing.
3. BJF Pitts and JN Pitts. (1986) Atmospheric Chemistry: Fundamentals and Experimental Techniques. Wiley.
4. DJ Jacob (1999). Introduction to Atmospheric Chemistry, Princeton University Press.
5. GM Masters (2004). Introduction to Environmental Engineering and Science. Prentice Hall.
6. I Colbeck (2008). Environmental Chemistry of Aerosols. Blackwell Publishing.

ME205P: PRACTICALS BASED ON ME205 (1 Credit)

ME206M. ENVIRONMENTAL IMPACT ASSESSMENT (MINOR) (2 Credits)

1. **Origin and Scope of EIA:** Origin of Environmental Impact Assessment (EIA); Principles and scope; Indian policies regarding EIA; Developmental projects requiring EIA; ISO 14000

2. **Steps of EIA:** Screening; Scoping; Impact prediction; Consideration and comparison of alternatives; Stakeholder involvement; Compensatory actions and mitigation measures; Preparation of EIA report; Review and decision making

3. **Methods for EIA:** Methods for organizing and presenting information: Ad Hoc Method; Checklists; Scales and Weights, Matrices; Networks and overlay approaches; Simulation Modelling, Spatially Based Methods; Rapid Assessment, Risk and Uncertainty in EIA

4. **Approaches to impact prediction:** Physical, experimental, computer and mathematical Models; Predicting quantitative & qualitative environmental changes in components of environment

5. **EIA for developmental programmes:** EIA for various Industries; Urban development; Energy projects; EIA for resources management

6. **Strategic environmental assessment:** Aims, principles and scope of Strategic Environmental Assessment (SEA); Importance and limitations; Procedures; Comparison of SEA and EIA

7. **Socioeconomic impact analysis:** Aims, Principles and scope of Socioeconomic Impact Analysis (SIA), Basic steps in SIA, Analysis of public services and facilities impacts; Fiscal impact analysis

8. **Case Studies:** Current case studies related to environmental impact assessment such as Narmada Project, Valley of Flowers, Coal Mining Projects

Suggested Readings

1. Abaza H, Bisset R, Sadler B (2004) Environmental Impact Assessment and Strategic Environmental Assessment: Towards an Integrated Approach. UNEP, Geneva
2. Anjaneyulu Y, Manickam V (2011) Environmental Impact Assessment Methodologies. CRC Press
3. Eccleston CH (2017) Environmental Impact Assessment: A Guide to Best Professional Practices. CRC Press

4. Lawrence DP (2003) Environmental Impact Assessment: Practical Solutions to Recurrent problems. John Wiley & Sons, Inc., New Jersey.
5. Morgan RK Environmental Impact Assessment: A Methodological Approach. Springer US.
6. Mareddy AR, Shah A, Davergave N (2017) Environmental Impact Assessment: Theory and Practice. Butterworth-Heinemann Pub
7. Wood C (2014) Environmental Impact Assessment: A Comparative Review. Routledge
8. Glasson J, Therivel R, Chadwick A (2013) Introduction to Environmental Impact Assessment. Routledge,
9. Hanna KS (2015) Environmental Impact Assessment: Practice and Participation. Oxford University Press

ME207: SCIENCE COMMUNICATION (THEMATIC REVIEW & PRESENTATION) (1 Credit)

ME208: STUDY TOUR/EXPERIENTIAL LEARNING (2 credits)

THIRD SEMESTER

ME301. STATISTICAL METHODS (2 Credits)

1. **Data and its properties:** Types of data; Scales of measurement; Data distribution; Tabular and Graphical presentation of data

2. **Descriptive statistics:** Populations and Samples; The Frequency distribution; Measures of central tendency, dispersion and shape; The normal distribution and Central Limit Theorem; Confidence intervals for population mean; The standard score

3. **Student's t test:** The nature of t distributions; One-sample t-test; Two-sample t-test; Repeated measures t-test; Unequal variance t-test

4. **Analysis of variance:** Assumptions for use of the ANOVA; The nature of F distribution; The completely randomized design; The randomized complete block design; The repeated measures design; Factorial experiments; Multiple comparisons of means

5. **Chi-Square tests:** The nature of chi-square distributions; Goodness-of-fit tests; Contingency table analysis; Relative risks and odds ratios

6. **Correlation and regression:** Scatterplot; The Pearson product-moment correlation coefficient; The regression line; The accuracy of prediction; Assumptions underlying regression and correlation; The Coefficient of Determination; Multiple Regression; Multiple Correlation and Partial Correlation

7. **Nonparametric statistics:** Distribution-free Tests; The Sign Test; The Wilcoxon Rank Sum Test for Independent Samples; The Wilcoxon Signed Rank Test for the Paired Difference Experiment; The Kruskal–Wallis Test for a Completely Randomized Test; The Friedman Test for a Randomized Block Design; Spearman Rank Correlation Coefficient

8. **Case studies:** Statistical analysis of Varanasi Census and Climate data using Excel, SPSS and R

Suggested Readings

1. Sokal RR, Rohlf JF (2009) Introduction to Biostatistics, 2nd Ed. Dover Publications, Inc., Mineola, New York.
2. Zar, JH (2009) Biostatistical Analysis, 5th Ed. Prentice Hall.
3. Reimann C, Filzmoser P et al. (2009) Statistical Data Analysis Explained: Applied Environmental Statistics With R. Wiley Online Library.
4. Weaver KF, Morales VC, Dunn SL, Godde K, Weaver PF (2018) An Introduction to Statistical Analysis in Research-With Applications in the Biological and Life Sciences. John Wiley & Sons, Inc.

ME301P. PRACTICAL BASED ON ME301 (1 Credit)

ME302.ENVIRONMENTAL MODELLING (2 Credits)

1. **Introduction:** Theory and practice of modelling; System simulation, types of models, modelling steps and ingredients; The modeller's toolkit

2. **Model formulation and implementation:** Model formulation; Physical models; Conceptual models; Mathematical models; Simulation models; Mechanistic models; Empirical models; Deterministic & stochastic models; Model validation: model accuracy
3. **Sensitivity and uncertainty evaluation:** Sensitivity analysis; Monte Carlo simulation; uncertainty evaluation; uncertainty boundary; Structure and parameter; Uncertainty in model outputs; Input data and equation errors
4. **Air pollution modelling:** Principles of air quality modelling; Plume height estimation; Gaussian distribution; Dispersion models: Eulerian Models, Lagrangian Models; Receptor models; Photochemical models; Model validation and uncertainties
5. **Hydrological modelling:** Fundamentals of water quality modelling; Ground and surface water modelling: aquifers contamination, salt water intrusions; Surface and ground water models and its application; Rainfall runoff modelling.
6. **Climate modelling:** Fundamentals of mesoscale modelling; Types of mesoscale models; Boundary and initial conditions; Coordinate systems; Parameterization schemes; and model application and evaluation; Basic principles of general circulation modelling; grid-point and spectral GCMs; Role of the ocean in climate modelling; Inter-annual variability of ocean fields; Concepts of ocean – atmosphere coupled models.
7. **Agriculture system modelling:** Introduction to crop growth modelling; Rate and state variables; Levels of crop productions: principal processes of the production levels; Uses of crop growth models; Modelling techniques; Simulation modules for water balance and crop growth
8. **Case studies**

Suggested Readings

1. Mike J. Barnsley (2007) Environmental Modelling: A Practical Introduction. CRC Press.
2. MZ Jacobson (2005) Fundamentals of Atmospheric Modelling. Cambridge University Press.
3. Thomas Stocker (2011) Introduction to Climate Modelling. Springer-Verlag Berlin Heidelberg.
4. Michael J Barnsley. (2006) Environmental modeling. CRC Press (Taylor and Francis Group)
5. Holzbecher.E (2011) Environmental Modeling. Springer.
6. Penning de Varies et al. , Simulation of ecophysiological processess of growth in several annual crops, IRRI, Los Banos and Pudoc, Wageningen

ME302P. PRACTICALS BASED ON ME302 (1 Credit)

ME303.GLOBAL CLIMATE CHANGE (2 Credits)

1. **Introduction:** Introduction to earth system science, monsoon, atmospheric and oceanic dynamics; Earth coordinate system; Radiation and energy balance; Carbon cycle; Atmosphere–land biosphere–ocean carbon exchange; human influence on climate, Physical oceanography, glaciology, paleoclimate

2. **Climate risk:**Air and water pollution; Acid rain and abatement technologies; Climate change, climate variability; Climate change science with emphasis on cryosphere, hydrosphere, atmosphere; Climate risk; Climate extremes

3. **Early warning system and communication:** Scientific understanding; Monitoring network and prediction methodology; Early warning to risk management agencies; Different scales of early warning-now cast, short, medium and long range forecasting; Communication links for early warning; Role and use of science and technology -Remote sensing & GIS, weather radars etc,; Agencies involved in early warning and their latest achievements

4. **Climate mitigation:**Greenhouse gases and global warming; Policies and programmes; Different mitigation strategies at local, national and international level

5. **Climate adaptation:** What is adaptation? How to adopt, when to adapt;System based approach;Policies and programmes, adaptation strategies in different sectors- water, agriculture, health etc.

6. **Management and planning:** Climate & cities, infrastructure, mobility and transportation, tourism, land uses planning; Environment planning & public participations; Governance and economic development by intelligent use of science and technology

7. **Tools & techniques:** Knowledge management and capacity building; Institutional mechanism and issues; Different tools and techniques – statistical methods, mathematical models, satellite information etc.; Mathematical models for climate, crop, water, ecological and pollution management and planning

8. **Case studies:** Water management, sustainable agriculture, health care, smart city, environment planning etc.

Suggested Readings

1. IPCC reports (2014), Cambridge
2. Bennette M R, Glasseer NF (2009) Glacial Geology; Ice Sheets & Landforms; 402p, Wiley Blackwell
3. David NJ (2011) Climate Change and Climate Modelling. Cambridge University Press.
4. Dessler AE (2012) Introduction to Modern Climate Change. Cambridge University Press.
5. Houghton J (2011) Global Warming: The Complete Briefing. Cambridge University Press
6. complete Briefing. Cambridge University Press

ME303P. PRACTICALS BASED ON ME303 (1 Credit)

ME304.WATER POLLUTION MANAGEMENT (2 Credits)

1. **Fundamental properties of water:** Physicochemical properties of water; Water use-classifications and water quality standard; Basic principles of contaminant behaviour in the environment

2. **Fundamentals of aquatic chemistry:** Concentration and activity, dissolution/precipitation reactions; Species distribution in freshwaters; Effect of oxygen-demanding waste on water

3. **Sources of water pollutants:** Sources of water pollution; Types of water pollutants, pollutants and their behaviour in water

4. **Water pollution in aquatic ecosystem:** Eutrophication; Acidification of lakes; Thermal stratification and dissolved oxygen; Bicarbonate buffering

5. **Water pollution monitoring:** Objectives of water pollution monitoring; Selection of monitoring locations; Sampling requirements; Measurement techniques

6. **Groundwater contamination:** Aquifers, hydraulic gradient, flow through aquifers, ground water flow velocity, contamination transport, control of ground water plumes

7. **Waste water treatment:** Water treatment system, principles of coagulation, flocculation, sedimentation, filtration, disinfection, hardness and alkalinity, water softening, desalination. Waste water treatment: Primary treatment, Biological treatment and other advanced treatment processes. Sludge treatment

8. **Water quality modelling:** Fundamentals of water quality modelling, modelling aquifers contamination, salt water intrusions, surface and ground water models and its application.

Suggested Readings

1. Steven C. Chapra (1993) Surface Water-Quality Modeling, McGraw Hill Boston
2. A.K. Rastogi (2008) Numerical Groundwater Hydrology, Penram International Publishing Pvt. Ltd., Bombay.
3. Masters, G.M. (2004) Introduction to environmental engineering and science. Prentice-Hall of India Pvt. Ltd., New Delhi.
4. Metcalf and Eddy (1997) Wastewater Engineering: Treatment, Disposal, Reuse by, TataMc Graw Hill, Third Edition.
5. Sawyer (2005) Chemistry for Environment Engineering and Science. Tata Mc Graw Hill

ME304P. PRACTICALS BASED ON ME304 (1 Credit)

ME305. AIR POLLUTION MANAGEMENT (2 Credits)

1. **Sources of air pollutants:** Natural constituents of air; Variation in pressure and temperature; Spatial and temporal scales of atmospheric processes; Sources of air pollution, types of air pollutants, organic and inorganic pollutants, their behaviour and fate on local, regional and global scale

2. **Indoor air pollution:** Pollutants of indoor air, their sources, fate and health impacts; Sick building syndrome; volatile organic compounds; Bioaerosols; Building ventilation

3. **Air pollutants and its effect:** Emission sources of primary pollutants; Volatile organic compounds, persistent organic pollutants; Secondary pollutants and their sources; Emission factors; Natural and anthropogenic sources; Effect of air pollutants on biota and materials

4. **Measurement of gases and particulates:** Objectives of air pollution monitoring; Selection of monitoring locations; Sampling requirements; Measurement techniques; Gas sampling and measurement systems; Particle sampling and measurement systems; Monitoring of indoor air quality

5. **Representation of air quality data:** Diurnal and seasonal variations; Frequency distributions; Particle ratios; Pollutant standards indices; Air pollution indices; Emission inventories its concept and methodologies; Air quality norms and standards

6. **Air pollution control:** Air pollution prevention and control technologies; Gas specific removal technologies; Removal of particulate matter, catalyst system for vehicular emission control; Green technology; Legal control of air pollution

7. **Air pollution modelling:** Principles of air quality modelling; Deterministic, stochastic and simulation models; Dispersion models - Gaussian models, Box models, Eulerian Models, Lagrangian Models; Receptor models; model validation and uncertainties

8. **Case studies**

Suggested Readings

1. JH Seinfeld and SN Pandis (2016). Atmospheric Chemistry and Physics. Wiley.
2. J Colls (2002) Air Pollution. Spon Press.
3. GM Masters (2004). Introduction to environmental engineering and science. Prentice-Hall.
4. G Kiely (2007). Environmental Engineering. Tata McGraw-Hill.
5. B Sportisse (2009). Fundamentals in Air Pollution: From Process to Modelling. Springer.
6. RM Harrison (2007). Principles of Environmental Chemistry. RSC Publishing

ME305P. PRACTICALS BASED ON ME305 (1 Credit)

ME306. ENVIRONMENTAL METEOROLOGY (2 Credits)

1. **Climatology:** Fundamentals of climatology; Earth's radiation balance; latitudinal and seasonal variation of insolation, temperature, pressure, wind belts, humidity, water balance; air masses, monsoon, Jet streams, tropical cyclones and ENSO, classification of climates
2. **Physical meteorology:** Introduction to physical processes in the atmosphere, thermal structure of the atmosphere; Laminar and turbulent flow; atmospheric turbulence; atmospheric stability; mixing height; temperature inversion; atmospheric thermodynamics; radiative transfer; Greenhouse effect; adiabatic process of moist air; lightning; storm; Vertical stability of the atmosphere.
3. **Cloud Physics:** Cloud classification; condensation nuclei; growth of cloud drops and ice-crystals; precipitation mechanisms; artificial precipitation, hail suppression, fog and cloud; radar observation of clouds and precipitation.
4. **Dynamic meteorology:** Fundamental forces, pressure, gravity, centripetal and Corolis forces; geostrophic and gradient winds; atmospheric turbulance; planetary boundary layer, plume dispersion, meteorological models.
5. **Synoptic Meteorology:** Weather observations and transmission; hazardous weather elements like thunderstorms, tornadoes. Tropical meteorology; ITCZ; monsoon depressions; western disturbances; Indian monsoon; fronts, frontogenesis and frontolysis; cyclones and anticyclones.
6. **General Circulation:** Observed zonally symmetric circulations, angular momentum and energy budgets; east-west circulations in tropics; global wind circulation; ocean circulation; Basic principles of general circulation modelling.
7. **Numerical weather prediction:** Concept of NWP, concept of parametrization, NWP equations, vertical coordinates, resolutions, domain and boundary conditions, model errors, model comparisons.
8. **Case studies:** Some specific case studies.

Suggested Reading

1. H.R. Byers (1959) General Meteorology. McGraw-Hill Publishers.
2. F.W. Cole (1975) Introduction to Meteorology. Wiley.
3. S.Q. Kidder and T.H. Vanderhaor (1995) Satellite meteorology: An introduction.
4. W. Zdunkowski and A. Bott. Dynamics of Atmosphere (2003). A course in Theoretical Meteorology. Cambridge University Press.
5. DS Lal (2001) Climatology. Sharda Pustak Bhawan
6. J Marshall, RA Plumb (2007). Atmosphere, Ocean and Climate Dynamics: An Introductory Text. Academic Press.

ME306P. PRACTICALS BASED ON ME306 (1 Credit)

ME307. CLIMATE DYNAMICS (2 Credits)

1. **Principles of thermodynamics**: First law of thermodynamics; Internal energy, specific heat capacity and enthalpy; Adiabatic process, entropy and the second law of thermodynamics

2. **Thermodynamics of water vapour and moist air**: Isotherms, equation of state of moist air; Clausius Clapeyron equation; Adiabatic processes of saturated air and moisture variables

3. **Hydrostatic equilibrium**: Hydrostatic equation; Geo-potential height computations for upper-air sounding; Hydrostatic of homogeneous, isothermal, constant lapse rate and dry adiabatic atmosphere;Standard atmosphere; Hydrostatic stability and instability; General consideration; Slice method; Entrainment

4. **Fundamental forces and its equations**: Gravitation and gravity; Geo-potential; Equation of motion in different coordinate systems; Tangential, local, rectangular coordinates, spherical polar coordinates, natural coordinates, scale analysis of the equations of motion, approximate equations; Rossby number; Continuity equation in cartesian, isobaric and spherical coordinate; Inertial wind, geostrophic wind, gradient wind, cyclostrophic wind and thermal wind, isallobaric wind

5. **Viscosity and turbulence**: Fundamental laws of viscosity;Equations of mean motion in turbulent flow, mixing length theory, planetary boundary layer, power law, Ekman layer, Richardson number, Raynold's number, Froud number, Kelvin's circulation theorem, Bjerknes theorem, potential vorticity, vorticity equation, divergence equation, Helmholtz theorem, Tendency equation, BjenknesHolmboe theory

6. **Numerical methods**: Finite difference; Truncation error; Linear computational instability; Neuman condition, implicit and semi-implicit method, relaxation method, simultaneous and sequential

7. **Atmospheric waves**: Perturbation theory; Properties of waves, sound waves, gravity waves, vertical stability, internal gravity waves, Rossby waves, mountain waves

8. **Numerical weather prediction**: Historical review, filtering of sound and gravity waves, filtered forecast equation, forecasting of stream function; Barotropic model, equivalent barotropic model, baroclinic model-two level, multilevel quasigeostrophic model, primitive equation models, spectral and finite element model; Sigma coordinate, hydrodynamic equations in Sigma coordinate, Eta coordinate, Eta model; Precipitation forecasting, range of predictability.

Suggested readings:

1. SL Hess and Winston (2006). Introduction to Theoretical Meteorology. Krieger Publishing Company.
2. AH Gordon, G Warwick, P Schwedtfeger, RB Scott (2016). Introduction to Dynamic Meteorology. Routledge.
3. J Holton, GJ Hakim (2012). An Introduction to Dynamic Meteorology. Academic Press.
4. GJ Haltiner (1971). Numerical Weather Prediction. Wiley.
5. Pisharoty. IMD Technical Note on Thermodynamic Diagram and some of Their Uses.
6. HA Dijkstra (2013). Nonlinear Climate Dynamics. Cambridge.

ME307P. PRACTICALS BASED ON ME307 (1 Credit)

ME308. ENVIRONMENTAL GEOCHEMISTRY (2 Credits)

1. **Principles of environmental geochemistry**: Types of rocks and rock cycle; Radioactivity in the environment; Radioactive elements in rocks, radioelements in soils and water, environmental aspects of radionuclide

2. **Geochemistry and water quality**: Measures of water quality; Chemical analysis, graphic representation, physical analysis, biological analysis.

3. **Concepts of major, trace and rare earth elements**: Classification of trace elements; Mobility of trace elements and biogeochemical cycles; The distribution of elements earth's interior and rocks.

4. **Hydrogeochemistry:** Chemical potential and activity of solutions; Rates, mechanisms, and elementary reactions; Acid and Bases; Carbonate System; Metal Complexation, assessment of metal pollution in soils and water, sources and types of metal pollution

5. **Weathering**: Types of weathering; Agents of weathering; Role of weathering in soil formation: Re-distributions of chemical elements by weathering,

6. **Geochemistry applied to agriculture**: Sources of trace elements in soils; Trace element problems in crops and livestock; Assessment of metal pollution in soils, sources and types of metal pollution, assessment of metal pollution.

7. **Geochemistry and human health**: Essential elements; Toxic and other elements, special problems of health and environment, trace elements and diseases, natural trace element poisoning.

8. **Case studies**

Suggested readings

1. F Albarede (2003). Geochemistry: An Introduction. Cambridge.
2. BSLollar (2005). Environmental Geochemistry. Elsevier.
3. WM White (2013). Geochemistry. Wiley.
4. FR Siegel (2002). Environmental Geochemistry of Potentially Toxic MetalsSpringer.
5. GN Eby (2004). Principles of Environmental Geochemistry. Waveland Press.
6. HD Holland, KK Turekian (2004). Treatise on Geochemistry. Elsevier.

ME308P. PRACTICALS BASED ON ME308 (1 Credit)

ME309. URBAN ENVIRONMENT (2 Credits)

1. **Urban environment:** Dynamics of urban systems, cities as human and ecological systems; human resources, principles of urban environmental management, resilience in urban ecosystem.

2. **The origin and growth of cities:** Origin of cities, evolution of settlement pattern, changes in land use and land cover due to urbanization.

3. **Monitoring urban growth:** Mapping, measurement, analysis and simulation of urban growth, use of remote sensing for urban growth mapping.
4. **Issues of urban quality of life:** Urban air quality, heat islands; sanitation, waste management, energy conservation, traffic management and related issues, global climate change and cities.
5. **Urban waste and water management:** Sources of urban waste, compositions, control and management, urban water use, waste water management.
6. **Urban environmental planning and risk assessment**: Principles of urban environmental planning, Open space preservation, urbanization and environmental impacts, urban transport and sustainability, risk assessments in urban environment.
7. **Governance for sustainable city and legal issues:** Urban governance-concepts and practices; geopolitical and economic aspects, urban legal and policy frameworks, strategies for sustainability.
8. **Cases studies**

Suggested readings:

1. Ramachandran R. (1989) Urbanisation arid Urban Systems in India, Oxford University Press, New Delhi
2. Mandal, R.B. (1988) Systems of Rural Settlements in Developing Counties, Concept Pub. Co., New Delhi.
3. Kahn, M.E. 2006. Green cities: urban growth and the environment. Brookings Institution Press.
4. Hanaki, K. 2008. Urban environmental management and technology. Springer Verlag.
5. R M Harrison, R E Hester (2009) Air Quality in Urban Environments. RSC Publishing.

ME309P. PRACTICALS BASED ON ME309 (1 Credit)

ME310.COMPUTERPROGRAMMING (2 Credits)

1. **Introduction:** Concepts and principles of computer programming; Applications of computer programming relevant to environmental fields; Big data analysis; Artificial Intelligence; Machine learning
2. **Programming tools and software:** An introduction to programming resources, Operating systems, Installation, Input, Processing, Output, Coding and decoding, Operating procedure and implementation
3. **Programming languages:** Programming languages-an introduction to the theory, design, and implementation of programming languages (Fortran, C++, Python etc.)
4. **C++ and FORTRAN for environmental programming:** Basics, code design and execution
5. **R for environmental programming:** Basics, code design and execution
6. **Matlab for environmental programming:** Basics, code design and execution
7. **Python and IDL for spatial data analysis:** Basics, code design and execution
8. **Case studies**

Suggested Readings

1. MH Trauth (2016). MATLAB® Recipes for Earth Sciences. Springer.

2. Brunsdon and Comber (2015) An Introduction to R for Spatial Analysis and Mapping. Sage Publishing.
3. Lawhead (2013) Learning Geospatial Analysis with Python. PACKT.
4. Kaiser and messer. (2011) Mathematical Programming for Agricultural, Environmental, and Resource Economics. Willey

ME310P. PRACTICALS BASED ON ME310 (1 Credit)

ME311. WATER RESOURCE MANAGEMENT (2 credits)

1. **Introduction to water resources**: Global water resources; Hydrologic cycle; Interrelation of water resources with other natural resources and the environment; Concept of sustainable water resources development; Water and ecosystems

2. **Management of water resources:** Why management, what about to be managed, how to manage; Functions of water resources management; Water scarcity and its impacts, concept of environmental water management

3. **Integrated water resources management (IWRM**): Definition of IWRM; IWRM Principles, implementation, legislative and organizational framework IWRM; Urban water resources management; Irrigation management; Watershed conservation and management

4. **Water Resource Systems:** Basics and principles; Surface and groundwater management; Conceptual and lumped parameter models; Systems analysis in water resources; Water quality, water quantity and water budget
5. **Basic techniques for water analyses**: Rainfall analysis, soil water content analysis evaporation, transpiration and evapotranspiration, flood measurement rainfall-runoff analysis, design of flood peak; Remote Sensing and GIS for water resources

6. **Water resource needs-** Consumptive and non-consumptive water use; Estimation of water requirements for irrigation, for drinking and navigation: Water budget and development plan

7. **Environmental legislation**: Legal aspects of water resources; Environmental impacts assessment guidelines

8. **Case studies**

Suggested Readings

1. D K Todd & L W Mays (2004) Groundwater Hydrology, Wiley publication
2. K. Subramanya (1994) Engineering hydrology. Tata McGraw Hill.
3. Neil S. Grigg (1996) Water Resources Management: Principles, Regulations, and Cases, McGraw Hill.
4. RQ Grafton and Hussey (2011). Water Resources Planning and Management. Cambridge Press
5. Vaidyanathan (2008). India's Water Resources: Contemporary Issues on Irrigation. Oxford University Press.

ME311P. PRACTICALS BASED ON ME311 (1 Credit)

ME312. ENVIRONMENTAL INSTRUMENTATION (2 Credits)

1. **Basics of Instrumentation and measurements**: Basics of Instrumentation and measurements of physical parameters; Units of concentration; Qualitative and quantitative instrumental

analysis, sensitivity and selectivity, dynamic range, calibration, data generation; Data management and quality control; Data processing and documentation; Quality assurance and quality control

2. **Chemical methods:** Gravimetric and Volumetric techniques; Chemiluminescence; Chemical Amplification; Electrochemistry; Electrophoresis and its environmental applications

3. **Chromatographic techniques:** Principle and classifications of chromatography; Gas and Liquid chromatography: sample preparation and injection, detection; calibration and quality control; Advanced chromatographic techniques: GC-MS, LC-MS, ICP-MS

4. **Spectroscopic Techniques:** Fundamentals; Principles and measurement approaches for Atomic Absorption Spectroscopy; Mass spectrometry; Electron Spectroscopy; Fourier Transform Spectroscopy; IR; Laser; X-Ray and NMR Spectroscopy

5. **Microscopic techniques:** Fundamentals; Types; Principles of Optical microscopy; Electron microscopy and scanning probe microscopy; X-Ray Microscopy; Scanning Electron Microscopy; Transmission Electron Microscopy; Focused Ion Beam and Atomic Force Microscopy; Applications

6. **Optical techniques:** RADAR; LIDAR; AWS; Temperature (dew point and dry bulb temperature); AOD; Ensemble scattering techniques: light Scattering

7. **Electrochemical Techniques:** Introduction; Conductivity of solution' electrochemical methods and potentiometry, voltammetry-polarography, potentiometry titration

8. **Radioactivity**: Radioactivity and rate of radioactive decay; Measurement of radioactivity; Brief idea of radiation dosimetry; Measurement of stable isotopes; Applications of isotopes in environmental analysis

Suggested Readings:

1. McMahon G (2007) Analytical instrumentation: a guide to laboratory, portable and miniaturized instruments. Wiley.
2. Radojević M, Bashkin VN (2006) Practical Environmental Analysis. Royal Society of Chemistry
3. Rouessac F, Rouessac A (2007) Chemical analysis: modern instrumentation and methods and techniques. Wiley.
4. Skoog DA, Holler FJ, Crouch SR (2007) Principles of instrumental analysis. Thomson Brooks/Cole.
5. Down RD, Lehr JH (2005) Environmental instrumentation and analysis handbook. Wiley-Interscience.

ME312P. PRACTICALS BASED ON ME312 (1 Credit)

ME313. GLACIOLOGY (2 Credits)

1. **Distribution of glaciers and snow cover:** Importance of glaciers; General principle of the meteorology of precipitation, formation of snow, physical characteristics of snow crystals, areal distribution of glaciers/snow cover and factors controlling the distribution of snow cover

2. **Morphology of glaciers:** Classification of glaciers; Crevasses and icefall; Moraines; Dead ice; Depositional and erosional landforms of glacier

3. **Transformation of snow to ice:** Different types of metamorphism; Transformation of snow into ice; Zones in a glacier, effect of metamorphism on albedo of snow and ice, grain growth

4. **Paleoglaciation:** Milankovitch cycles and greenhouse effect; Little ice age (LIA); Glacial and interglacial cycles

5. **Distribution of temperature in glaciers:**Thermal parameters of snow/ice; Types of glacier based on temperature distribution, temperature profiles; Seasonal variation of temperature as function of depth

6. **Flow and sliding of glaciers:** Driving and resisting stresses; Vertical profile of flow; Simple models of glacier flow, deformation, steady and non-steady flow of glacier

7. **Glacier and changing climate:** Summer and winter mass balance; Response of glaciers to climate change; Reaction to change in mass balance and reaction to additional forcing

8. **Case studies**

Suggested readings

1. DI Benn and DJA Evans (2010). Glaciers and Glaciations. Wiley.
2. Barry and Gan (2011): The Global Cryosphere: Past, Present and Future. Cambridge University Press.Routledge.
3. Cuffey and Paterson (2010). The Physics of Glaciers, 4th edition.
4. P. J. Knight (1999): Glacier Science and Environmental Change. Wiley.
5. Hambrey and Alean (2004): Glaciers, 2nd edition. Cambridge University Press.
6. S. J. Marshall (2011). The Cryosphere. Princeton University Press.

ME313P. PRACTICALS BASED ON ME313 (1 Credit)

ME314. OCEANOGRAPHY (2 Credits)

1. **The Earth and the ocean:** Introduction: geography of the oceans; Early exploration of the seas; The Beginnings of ocean science; Current and future; Earths structure; Physiography of oceans- origin and evolution of ocean basins (continental and oceanic basins)

2. **Plate Tectonics and the ocean floor:** Earth structure; Plate boundaries; Continental drift; Sea floor spreading; Plate tectonics; Shelf and deep sea sedimentation; Origin and morphology of ocean basin and margins

3. **Water and seawater:** Water molecule: water's thermal properties; Water density; Seawater; Dissolved components added and removed from seawater; Dissolved gases in seawater; Acidity and alkalinity of seawater; Processes affecting seawater salinity; Surface and depth salinity variation; Comparing pure water and seawater

4. **Air-sea interaction:** Uneven solar heating on Earth; The Coriolis effect; Atmospheric circulation cells on a spinning earth; The oceans, weather, and climate; Sea ice: icebergs

5. **Ocean circulation:** Measuring ocean currents; Surface currents; Upwelling and down welling surface currents of the oceans; Deep currents; Western boundary currents: The Gulf Stream and Kuroshio; Eastern boundary currents: The California current system, equatorial currents, El Niño southern oscillation, Antarctic circumpolar current, Currents of the Indian Ocean

6. **Marine Provinces:** Bathymetric techniques: Airborne electromagnetic bathymetry; Use of DEM; Palynology as a tool in bathymetry; The hypsographic curve; Provinces of the ocean floor.

7. **Marine environment and pollution:** Distribution of life in the oceans; Adaptations of organisms to the marine environment; Divisions of the marine environment; Primary productivity andphotosynthetic marine organisms; Regional productivity; Energy flow; Laws and regulations; Ecosystems and fisheries; Mariculture; Types of marine pollution; Other concerns

8. **Case studies**

Suggested Readings

1. HV Thurman and AP Trujillo (2004). Introductory Oceanography. Pearson.
2. SR Emerson and JI Hedges (2008). Chemical Oceanography and the Marine Carbon Cycle. Cambridge.
3. EB Frankel (1995). Ocean environmental management: A primer on the role of the oceans and how to maintain their contributions to life on Earth. Pearson.
4. A Trujillo and H Thurman (2013). Essentials of Oceanography. Pearson.
5. WS Chamberlin and T Dickey (2008). Exploring the World Ocean. McGraw-Hill.

ME314P. PRACTICALS BASED ON ME314 (1 Credit)

ME315. RADIATION & ISOTOPES (2 Credits)

1. **Fundamental concepts of elementary particles:** Atomic structure, atomic number & mass number, mass energy relation, fission and fusion processes; Radioactivity and different modes of disintegration; Radioactive decay, equations and half-life; Radioactivity, specific activity

2. **Stable Isotopes:** Introduction; Physics of the Nucleus; Electromagnetic Radiation: X-rays and Gamma rays, particle radiation (Alpha, Beta, Neutrons), stable isotopes (O, C, N, H) and their applications in environmental sciences

3. **Radiogenic Isotopes:** Cosmogenic Isotopes (^{14}C, ^{7}Be, ^{10}Be); Production and decay; Applications of radiogenic isotopes (C, U, Th, K, others) in environmental sciences

4. **Measurements of Radiation:** Units of Radiation; Radiation dosimetry; Radiation exposure and dose units; General properties of radiation detectors: Geiger-Mueller (GM) counters, liquid scintillation counters, solid scintillation detectors, ion chambers, proportional counters, counting statistics
5. **Nuclear and radiation techniques:**Applications in the physical, chemical, biological, earth, planetary, environmental science; Assessment of external and internal exposures; Biological effects of ionizing radiation

6. **Applications of Isotopes in Medicine:**Medical exposures in diagnostic radiology; Radiotherapy and nuclear medicine; Cancer Chemotherapy: basic principles, classification, mechanism of action: Indication &toxicity of cancer chemotherapy

7. **Safety measures and Radiation Protection:** Background radiation; Principles of radiation protection; Maximum permissible doses; Personnel monitoring; Regulatory control; Protection against occupational exposure and methods to minimize radiation exposure; Radiation safety in research laboratories

8. Case studies

Suggested Readings

1. GF Knoll (2011). Radiation Detection and Measurement, Wiley.
2. WM White (2013). Geochemistry. Wiley.
3. G Ottonello (1997). Principles of Geochemistry. Columbia University Press.
4. F Albarede (2004). Geochemistry: an Introduction. Cambridge.

ME315P. PRACTICALS BASED ON ME315 (1 Credit)

ME316.GEOINFORMATICS (2 Credits)

1. **Basic cartography:** Types of Maps; Describing and measuring the Earth; measuring height: the geoid; Coordinate systems; Datums; Geometric distortions and projection model

2. **Map projections:** Major map projections; Projection specification; World geographic reference system (GEOREF), Global Positioning Systems (GPS)

3. **Data collection and mining:** Spatial Data Collection; Spatial Data Management and Integration; Spatial Data Mining

4. **Geographic Information Systems:** Hardware and software components; Vector systems; Raster systems; Databases; GIS systems; GIS applications

5. **Spatial data analysis:** Classification of analytic GIS capabilities; Retrieval, classification and measurement; Overlay functions; Neighbourhood functions; Network analysis

6. **Data visualization:** GIS and maps; The visualization process; Visualization strategies; The cartographic toolbox, Mapping methods; Map cosmetics

7. **Image processing in GIS:** Map registration, stacking, indices, python script and programming in GIS

8. **Image analysis in GIS**: Visualization and radiometric operations; Geometric operations; Image enhancement and visualization; Visual image interpretation; Digital image classification; Integration

Suggested Readings

1. Barry F. Kavanagh (2002), Geoinformatics, Prentice Hall.
2. Charles D. Ghilani, Paul R. Wolf (2011), Elementary Surveying: An introduction to Geoinformatics. Pearson.
3. C. Lo, A. K. Yeung (2007), Concepts and techniques in geographic information systems Pearson Prentice Hall.
4. K. T. Chang (2006) Geographic information system, Wiley.
5. H. A. Karimi (2014) Big Data: techniques and technologies in geoinformatics, CRC Press.
6. Rudra Pratap. (2014)Getting Started with MATLAB: A Quick Introduction for Scientists and Engineers, Oxford University Pres

ME316P. PRACTICALS BASED ON ME316 (1 Credit)

FOURTH SEMESTER

ME401. DISSERTATION/THESIS WORK **(8 Credits)**

ME402.PRESENTATION **(2 Credits)**

(B) M.Sc. Environmental Sciences (Ecological Sciences)

FIRST SEMESTER

ME101. FUNDAMENTALS OF EARTH SYSTEM SCIENCE (2 Credits)

1. **The Earth and the solar system:** The solar system; Kepler's laws of planetary motion; Geological Time Scale; Age of the Earth; Basic principles of stratigraphy; Earth's gravity and thermal structure: geoid, spheroid; Isostasy

2. **Evolution of the Earth:** Modern theories on the origin of the Earth and other planetary bodies; Evolution of earth's atmosphere and oceans; Theories about the origin of life and the nature of fossil record: Earth's interior; Continental drift; Plate tectonics: mountain building; Volcanism; Earthquakes and Tsunamis

3. **Lithosphere:** Gross composition and physical properties of important minerals and rocks: properties and processes responsible for mineral concentrations; Nature and distribution of rocks and minerals in the earth and different parts of India; Genesis, classification and distribution of soils

4. **Atmosphere:** Vertical structure of atmosphere; Lapse rate, stability; Energy flow: conduction, convection, sensible and latent heat; Energy balance: radiation, absorption, scattering; Greenhouse gases and global warming; Radiative forcing, atmospheric boundary layer, dispersion of pollutants

5. **Hydro-and cryosphere:** Cryosphere; Fresh water and marine ecosystem; Oceanic heat and salinity balance; Ocean currents; Marine food and economic resources; Biological productivity of the oceans

6. **Atmospheric physics and chemistry:** Sources of trace gases and particulates in the atmosphere; Key processes in atmospheric chemistry: oxidation chemistry, halogen chemistry; Properties of aerosols, role and measurements; Ozone depletion; Clouds formation, cloud microphysical processes; Artificial rainmaking

7. **Earth's climate:** Classification of climate: Koppen's and Thornthwaite's scheme of classification; Ocean and climate; Atmosperic and ocean circulation; Genesis and characteristics of ENSO, El-Nino, ENSO and Indian monsoon; Climate modelling; Climate change and its impact; Climate change policy

8. **Case studies:** Case studies and success stories

Suggested Readings

1. CN Hewitt, AV Jackson (2009) Atmospheric Science for Environmental Scientists. Blackwell
2. JH Seinfeld, SN Pandis (2016) Atmospheric Chemistry and Physics. Wiley
3. SE Manahan (2010) Environmental Chemistry. Wiley
4. SE Cornell, IC Prentice, JI House, CJ Downy (2012). Understanding the Earth System - Global Change Science for Application. Cambridge
5. J Marshall, RA Plumb (2008). Atmosphere, Ocean and Climate Dynamics: An introductory Text. Elsevier
6. BJ Skinner, SC Porter, DB Botkin (2011). The Blue Planet: An Introduction to Earth System Science. Willey

ME101P. PRACTICALS BASED ON ME101 (1 Credit)

ME102. FUNDAMENTALS OF ECOLOGICAL SCIENCES (2 Credits)

1. **The scope of ecology:** The science of ecology; Historical development of ecological thoughts; Organization levels of ecological systems; Linking ecology and environmental issues

2. **The environment:** Biotic and abiotic environment and its interactions; Concept of limiting factors; Ecological adaptations; Habitat and niche concept

3. **Population ecology:** Population characteristics; Metapopulations; Population growth models; Concept of biotic potential and carrying capacity; Life history models (*r*&*K* selection); Factors regulating population growth

4. **Community ecology:** Nature of communities; Community interactions; Community structure and attributes; Species diversity and dominance

5. **Ecosystem ecology:** Ecosystem structure; Energy flow; Trophic levels; Food chains; Ecological pyramids; Ecological efficiencies; Trophic cascades; Ecosystem production, decomposition, Biogeochemical cycle of C, N and P; Nutrient cycling at ecosystem level

6. **Ecological succession:** Types; Mechanisms; Concept of climax; Steady state and stability in ecological systems; Ecosystem trends during succession

7. **Biogeography:** General features of major terrestrial and aquatic biomes; Theory of island biogeography; Biogeographical zones of India; Forest and grassland types of India

8. **Case studies:** Current case studies related to ecology; Dry tropical forests of India; Ecology of River Ganga

Suggested Readings

1. Odum EP, Barrett GW (2004) Fundamentals of Ecology (5th ed.). Brooks/ Cole Publishers
2. Krebs C (2009) Ecology: the experimental analysis of distribution and abundance (6th ed.). Pearson Benjamin Cummings, San Francisco.
3. Jørgensen SE (2010) Global Ecology (1st ed.) Academic Press
4. Stiling PD (2011) Ecology: Global Insights and Investigations. McGraw-Hill Education
5. Begon M, Howarth RW, Townsend CR (2014) Essentials of Ecology (4th ed.). Wiley
6. Velland M (2016**)** The Theory of Ecological Communities (MPB-57) (Monographs in Population Biology). Princeton University Press
7. Lawrence F (2017) Ecosystem Functioning & Restoration. Callisto Reference

ME102P: PRASCTICALS BASED ON ME102 (I Credit)

ME103. FUNDAMENTALS OF ENVIRONMENTAL BIOTECHNOLOGY (2 Credits)

1. **Introduction to biotechnology:** Historical Perspectives; Modern and old biotechnology; Biotechnology an interdisciplinary pursuit; Scope and future of environmental biotechnology

2. **Systems of molecular biology**: General organization of genetic material in prokaryotes and eukaryotes; Replication of genetic material; Gene and genetic code, transcription and translation, protein synthesis

3. **Techniques in biotechnology:** Biotechnology and its tools; Isolation and purification of genomic and plasmid DNA, RNA and protein; Electrophoresis; Polymerase chain reaction (PCR); Recombinant DNA techniques

4. **Basics of omics:** Concept and methods of genome, proteome, trancriptome and metabolome

5. **Basics of bioinformatics:** Application of information technology in biotechnology

6. **Biotechnology in environment:** Waste water and sewage treatment; Biofuels; Bioremediation: bioaugumentation, biotransformation, bioaccumulation; Biofertilizers; Biopesticides; Biological control in food security and biosafety

7. **Biotechnology in medicine:** Antibiotics; Vaccines; Gene therapy; Bio-pharmaceuticals; Bioreactors

8. **Case Study:** Classical and emerging issues of environmental biotechnology

Suggested Readings

1. Young MM (2011) Comprehensive Biotechnology. Second edition, Elsevier
2. Evans G, Furlong JC (2010) Environmental biotechnology: Theory and application. Oxford: Wiley-Blackwell
3. Fulekar MH (2010) Environmental biotechnology. Science Publishers
4. Jordening HJ, Winter J (2005) Environmental biotechnology: Concepts and applications. Wiley-VCH
5. Rittmann BE, McCarty PL (2001) Environmental biotechnology: Principles and applications. McGraw-Hill
6. Scragg AH (2005) Environmental biotechnology. Oxford University Press
7. Vallero D (2010) Environmental Biotechnology: A Biosystems Approach. Elsevier

ME103P. PRACTICALS BASED ON ME103 (1 Credit)

ANY ONE PAPER AS PER THE CHOICE BASED CREDIT SYSTEM (2 Credits)

ME109. EVOLUTIONARY &BEHAVIOURAL ECOLOGY (2 Credits)

1. **Evolution and behaviour:** Neo-Darwinism and the modern synthesis; Phylogeny and behaviour; Variation and heredity; Natural selection and 'selfish genes'; Cultural evolution

2. **Competing for resources:** Evolutionarily stable strategy; Resource defense; Ideal free distribution; Mating strategies and tactics

3. **Avoiding Attack:** Crypsis; Warning Signals; Mimicry

4. **Sexual selection, sexual conflict and mating systems:** Mate choice by resources; Mate choice by genes; Sensory bias; Conflict over mating; Mating systems with no male parental care; Mating systems with male parental care; Monogamy, polygyny, polyandry threshold; Female desertion and sex role reversal

5. **Parental care and family conflicts:** Types of parental care; Familial conflict, Sexual conflict, Parent-offspring conflict; Parent-offspring conflict resolution; Sibling-sibling conflict; Brood parasitism

6. **Social behaviors:** Altruism; Kin selection, Inclusive fitness; Kin recognition- Genetic cues, Environmental cues; Cooperation- Within species, Between species; Spite

7. **Communication and signalling:** The types of communication; The problem of signal reliability; Indices; Handicaps; Common interest; Human language; Dishonest signals

8. **Case studies:** Current case studies related to evolutionary and behavioural ecology

Suggested Readings

1. Davies NB, Krebs JR, West SA (2012) An Introduction to Behavioural Ecology, (4th Edition). Wiley-Blackwell
2. Alcock J(2013) Animal Behavior (10th ed). Sinauer Ass. Inc., Sunderland, Massachusetts
3. Krebs JR, Davies NB (Eds)(1997) Behavioural Ecology: An Evolutionary Approach, (4th ed). Wiley-Blackwell
4. Scott G(2004) Essential Animal Behaviour. Blackwell Science, UK
5. BarnardC(2004) Animal Behaviour-Mechanism, Development, Function and Evolution. Pearson
6. Westneat D, Fox C (2010) Evolutionary Behavioural Ecology. Oxford University Press
7. Barnard CJ (2012)Animal Behaviour: Ecology and Evolution. Springer
8. Clarke J(2017) Behavioral Ecology. Syrawood Publishing House

ME106M. ENVIRONMENTAL LAW & POLICIES (MINOR) (2 Credits)

1. **Environmental protection in India**: Historical and modern mechanisms for environmental protection in India; Rules and regulations of central and state Government for environmental protection; Common law remedies

2. **National policy on environment:** National Committee on Environment and Planning (NCEP); National forest policy; National water policy; National energy policy; National wetland policy

3. **Constitutional provisions for environmental protection:** Constitutional provisions for environmental protections: fundamental duties of citizen and directive principles of state policy; Writ provisions for the protection of environment

4. **National environmental Acts:** The Water (Prevention and Control of Pollution) Act, 1974; The Air (Prevention and Control of Pollution) Act, 1981; The Environment (Protection) Act, 1986; Mining Act, 1952; Factories Act; Motor Vehicle Act; Hazardous Waste legislation for pollution abatement; Hospital Waste Management

5. **National legislations on forest and wildlife:** The Forest (conservation) Act, 1980; The Wildlife (Protection) Act, 1972; The Biological Diversity (Protection) Act, 2002: aims, objectives and major contents; The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006

6. **Environmental legislations related to coastal zones:** Ambit and applicability of coastal regulation zone (CRZ) rules; Marine protected areas

7. **Institutional mechanisms for environmental protection:** Jurisdiction of High Courts, Supreme Court and Green Tribunal; Public interest litigation (PIL); Duties and functions of MoEF & CC; CPCB and SPCBs; NGT

8. **International environmental laws and treaties:** International agreements, conventions, treaties related to environment and sustainable development; Environmental quality and transboundary issues; Role of international agencies on environmental protection

Suggested Reading

1. Salzman J, Thompson Jr. B (2017) Environmental Law and Policy (Concepts and Insights) 3rd Edition, Foundation Press
2. Doabia TS (2017) Environmental and Pollution Laws in India, Vol I, LexisNexis
3. Doabia TS (2017) Environmental and Pollution Laws in India, Vol II, LexisNexis
4. Reddy KV (2013) Environmental Law, Asia Law House
5. Naseem M, Naseem S (2014) Environmental Laws in India (2nd Edition), Wolters Kluwer Law & Business

ME107M. SUSTAINABILITY SCIENCE (MINOR) (2 Credits)

1. **Foundations & history:** The emergence of sustainable development: its formative ideas and roots in development and environment debates; Key concepts and principles; The system dynamics of a finite planet; Basic thermodynamic and material laws and principles; Resource scarcity and carrying capacities

2. **Environmental justice:** The problem of allocation in the context of limits; The concept of environmental space and environmental inequality; Inter- and intra-generational justice; Contraction and convergence; Human rights to a safe environment

3. **Sustainable materials, technology and design:** The transformation of production process, infrastructures and systems; Concepts of resource efficiency, dematerialization, decoupling, clean or sustainable technologies, design for the environment, design for sustainability; Industrial ecology; Life cycle analysis

4. **Consumption, lifestyle & communication:** Getting to grips with the complexity of consumption and lifestyle; understanding people's motivations, attitudes, values and behaviours; The dynamics of transition and social change; The importance of gender issues in sustainable development

5. **Governance for sustainability:** Basic framing of the problem of governing common pool resources; history of governance, the social contract, 'governmentality'; Policy responses to sustainability; Agenda 21, UN SDGs

6. **The good life, development & wellbeing:** Wellbeing, quality of life and sustainability; sustainability as capabilities for flourishing within ecological limits; Philosophical and ethical dimensions of sustainable development

7. **Measuring sustainability:** Sustainability indicators; Research methods and reporting: tools, statistics and accounting

8. **Case studies:** Current case studies related to sustainability science

Suggested Readings

1. Daly HE (1996) Beyond Growth: the Economics of Sustainable Development. Beacon Press
2. Daly HE, Farley J (2010) Ecological Economics: Principles and Applications. Island Press
3. Elliott JA (2006) An Introduction to Sustainable Development. Routledge
4. Roosa SA (2010) Sustainable Development Handbook, Second Edition. Fairmont Press
5. Strange T, Bayley A (2008) Sustainable Development: Linking Economy, Society, Environment. OECD
6. Heinrichs H, Martens P, Michelsen G, Wiek A. (2015) Sustainability Science: An Introduction. Springer

7. Filho WL (2017) Handbook of Sustainability Science and Research, Springer
8. Dedeurwaerdere T (2014) Sustainability Science for Strong Sustainability, Elgar Publishing

ME108M. DISASTER RISK MANAGEMENT (MINOR) (2 Credits)

1. **Introduction and overview:** Understanding the concepts and definitions of hazard, disaster, and vulnerability; Risk: types, trends, causes and consequences of disasters; Disaster profile of India.

2. **Institutional framework, policy and guidelines:** Evolution of disaster management in India; Organisation and structure of disaster management in India; National policy on disaster management; National plan on disaster management.

3. **Prevention and mitigation**: Prevention and mitigation; Mainstreaming of disaster risk reduction in developmental strategy; National disaster mitigation fund

4. **Preparedness and response:** Disaster management cycle; Institutional arrangements; Crisis management plan and standard operating procedures; Role of Central and State Governments, National Emergency Operation Centre; National and State Disaster Response Force

5. **Recovery, reconstruction and rehabilitation:** Nature of recovery; Guiding principles for post-recovery, assessment, sustainability in recovery process; Guidance notes on recovery

6. **Capacity development, financial arrangements and international cooperation**: National institutions and disaster management centres in the States; Financing the relief expenditure; Hyogo Framework of Action; Agencies of United Nations involved in disaster management

7. **Application of Science and Technology**: Use of Remote Sensing, GIS and GPS; Early warning and disaster communication; Land use planning; Nature based solutions

8. **Case Studies**: Mega disasters of India and other parts of world.

Suggested Readings

1. MHA (2011) Disaster Management in India, Ministry of Home Affairs (MHA) Govt. of India, New Delhi
2. Srivastava HN, Gupta GD (2006) Management of Natural Disasters in Developing Countries, Daya Publishers, Delhi
3. Phillips, B (2009) Disaster Recovery. CRC Press
4. Oosterom V et al (2015) Geo-information for Disaster Management, Springer
5. Coppola DP (2015) Introduction to International Disaster Management, 3rd Edition, Elsevier

SECOND SEMESTER

ME201. ENVIRONMENTAL CHEMISTRY & TOXICOLOGY (2 Credits)

1. **Introduction to environmental Chemistry:** Fundamentals of Environmental Chemistry; Scope and future prospects; Tools and techniques in Environmental Chemistry

2. **Chemistry of air:** Physical and chemical properties; Air pollution: sources, sinks of air pollutants and management

3. **Chemistry of water:** Physical and chemical properties; Water pollution: sources, sinks of water pollutants and management

4. **Chemistry of soil:** Physical and chemical properties; Soil pollution: sources, sinks of soil pollutants and management

5. **Toxicity testing and dose response relationship:** Principles and Standards of toxicity testing; Methods in toxicity evaluation at genetic, cellular and molecular level by *in-vivo* and *in-vitro* methods; Dose-response relationship; Detoxification mechanisms in plants, animals and human beings

6. **Toxicity of xenobiotics**: Cellular, molecular and biochemical effects of xenobiotics including persistent organic pollutants (POPs) in living organisms; Remedial measures for reducing POPs toxicity

7. **Toxicology of microbial toxins:** Microbial toxins in environment; Cellular, molecular and biochemical effects of microbial toxins in humans and animals; Food poisoning and control measures

8. **Case studies:** Minamata disease in Japan; Bhopal disaster; Endosulfan pollution in Kerala; Arsenic poisoning in Indo-Gangetic plain and other emerging ecotoxicological issues

Suggested Readings

1. Vanloon GW, Duffy SJ (2010) Environmental Chemistry: a global perspective. Oxford University Press.
2. De AK (2000) Environmental Chemistry, 4thedition. New age International (P) Ltd.
3. Johnson DO, Netterville JT, Wood JC, James M (1973) Chemistry and the Environment.W.B. Saunders Company.
4. Lave LB,Upton AC (1987) Toxic Chemicals, health and the Environment. TheHopkins Press Ltd.
5. Manhan (2000) Environmental Chemistry, 7thedition. CRC Press.
6. Midoand Y, Satake M (2003) Chemicals in the environment. Discovery Publishing House.

ME201P. PRACTICALS BASED ON ME201 (1 Credit)

ME202M. ENVIRONMENTAL ISUES & CHALLENGES (MINOR) (2 Credits)

1. **Man and environment:** Impact of human population on environment; Ethical issues regarding unscientific development and environmental degradation; Impact of global land cover and

land use change; Causes, effects and mitigation strategies for global climate change and stratospheric ozone loss

2. **Environmental pollution:** Causes and effects of air, water, soil, noise, radioactive pollution; Basic pollution abatement practices and technologies

3. **Biotic invasions:** Extent and mechanisms of biological invasions; Ecological and economic impacts; Management strategies

4. **Loss of biodiversity**: Threats and pattern of biodiversity loss; Natural and anthropogenic causes; IUCN threat categories, Red data books; Conservation and restoration of biodiversity

5. **Global water crisis:** Distribution, withdrawal and consumption patterns; Causes and effects of water crisis; Water conservation approaches

6. **Global energy crisis:** Sources of energy supply; Current potential and future prospects of energy sources; Energy crisis; Energy conservation strategies

7. **Challenges of urbanization:** Recent trends of urbanization; Environmental impact of urbanization; Concept of green cities

8. **National policies and action plan on environment:** National Forest Policy; National Water Policy; National Energy Policy; National Action Plan on Climate Change; National Biodiversity Action Plan; Carbon crediting; Green taxes; Clean development Mechanisms

Suggested Readings

1. McConnell R (2008) Environmental issues: An introduction to sustainability. Pearson
2. Wali MK., Evrendilek F, Fennessy M (2009) The environment: science: Issues and solutions. CRC Press
3. Neelin J (2011) Climate change and climate modelling. Cambridge University Press
4. John Marshall R, Plumb A (2008) Atmosphere, ocean and climate dynamics: An introductory text. Elsevier
5. Phillips B, Thomas D, Fothergill A, Blinn-Pike L (2009) Social vulnerability to disasters. CRC Press
6. Hill M (2010) Understanding environmental pollution. Cambridge University Press
7. Morin FJ, Orsini A (2015) Essential Concepts of Global Environmental Governance. Routledge
8. Vig NJ, Kraft ME (2015) Environmental Policy: New Directions for the Twenty-First Century, (9th ed.). CQ Press

ME203. NATURAL RESOURCE MANAGEMENT (2 Credits)

1. **Introduction:** Types of natural resources, their consumption patterns; Human population explosion and resource degradation and conservation; Factors influencing resource availability, distribution and uses; Ecological, social and economic dimension of resource management

2. **Land resources:** Current status of national and global land resources; Land degradation: natural and anthropogenic drivers; Sustainable strategies for land resource management; Role of indigenous and local knowledge (ILK) in land resource management

3. **Water resources:** Current status of national and global water resources; Water pollution; Sustainable strategies for land resource management; Integrated watershed management; Role of indigenous and local knowledge (ILK) in water resource management

4. **Forest resources:** Current status of national and global forest resources; Forest degradation: natural and anthropogenic drivers; Sustainable strategies for forest resource management; Role of indigenous and local knowledge (ILK) in forest resource management

5. **Marine resources**: Current status of global marine resources; Marine pollution: natural and anthropogenic drivers; Sustainable strategies for marine resource management

6. **Minerals resources**: Current status of mineral resources in India; Environmental impact of mineral exploitation; Sustainable strategies for mineral resources management

7. **Energy resources:** Current status of conventional and non-conventional energy sources; Environmental impacts of energy exploitation; Cleaner and alternative sources of energy; Sustainable strategies for energy resources management

8. **Case Studies:** Current case studies related to natural resource management in India

Suggested Readings

1. Singh JS, Gupta SR, Singh SP(2014) Ecology Environmental Science and Conservation, Chand Publishing
2. Pandey BW (2005) Natural Resource Management, Mittal Publications
3. Morin FJ, Orsini A (2015) Essential Concepts of Global Environmental Governance. Routledge, ISBN 978-0-41582-247-3
4. Anderson DA (2013) Environmental Economics and Natural Resource Management, Routledge
5. Knight RL, Bates SF (1995) A New Century for Natural Resources Management, Island Press
6. Chiras DD, Reganold JP (2013) Natural Resource Conservation: Pearson New International Edition: Cases and Moral Reasoning, Pearson Education Limited

ME203P. PRACTICALS BASED ON ME203 (1 Credit)

ME204. REMOTE SENSING & GIS (2 Credits)

1. **Basics of remote sensing:** Background and history of remote sensing; Fundamentals of remote sensing: electromagnetic radiation, energy matter interaction; Platforms and sensors; Characteristics of images; Optical and microwave satellites

2. **Digital image processing:** Digital image data formats; Image rectification and restoration techniques: geometric correction, radiometric correction and noise suppression, image histograms, density slicing; Image enhancement techniques: contrast manipulation, spatial filtering and edge enhancement, atmospheric correction of satellite images

3. **Geographic Information Systems:** Fundamentals of GIS, vector, raster and attribute data models, vector and raster data structure; Spatial data input and editing; Visualization and query of spatial data; Spatial data transformations, spatial analysis

4. **Multi-image manipulations:** Spectral rationing, vegetation indices; Principal components analysis; Multi and hyper-spectral image classification; Supervised and unsupervised algorithms; Object based classification

5. **Microwave remote sensing:** Introduction to microwave remote sensing; Radar and radiometer, radiative transfer; Microwave missions and products definitions

6. **Hyperspectral remote sensing:** Introduction to hyperspectral remote sensing, hyperspectral radiometer; Hyperspectral missions and products definitions

7. **Global navigational satellite system:** Basics of GNSS; Concept of global positioning system (GPS), working of GPS, types of GPS; Differential GPS; Future GPS and applications of GPS

8. **Case studies:** RS and GIS applications in air quality modelling, early warning, urban planning, biodiversity and forest mapping, snow cover simulation, ocean salinity, disaster management.

Suggested Readings

1. Islam T, Alexander YH, Wang KJ (2018) Remote Sensing of Aerosols, Clouds, and Precipitation. Elsevier
2. Burrows JP, Platt U, Borell P (2014) The Remote Sensing of Tropospheric Composition from Space. Springer
3. Kokhanovsky AK, Leeuw GD (2013) Satellite aerosol remote sensing over land. Springer
4. Joseph G (2009). Fundamentals of Remote Sensing. University Press
5. Huisman O, de RA (ed.) Principles of Geographic Information Systems, Fourth edition. ITC Educational Textbook Series. ITC, Enschede, The Netherlands

ME204P. PRACTICALS BASED ON ME204 (1 Credit)

ANY ONE PAPER AS PER THE CHOICE BASED CREDIT SYSTEM (2 Credits)

ME209. CONSERVATION BIOLOGY (2 Credits)

1. **Defining conservation and its goals:** What is conservation? The emergence of conservation biology as a science; The emergence of global conservation; Values and Ethics in Conservation; Religious traditions and conservation

2. **Protected areas:** What is a protected area? History of protected area designation; Criteria for measuring conservation value of areas; Practical approaches to protected area designation; Design and management of protected areas; Management of semi-natural communities; Monitoring change in protected areas

3. **Genetic information and techniques in conservation:** Relatedness, taxonomy, and phylogeny; Techniques used for deriving genetic information: Allozyme electrophoresis; The polymerase chain reaction as a Non-invasive Method for Genotyping Endangered species; Random amplified polymorphic DNA (RAPD) Analysis; DNA fingerprinting; restriction fragment length polymorphism (RFLP)

4. **Conservation at genetic levels:** Measuring genetic diversity in populations; Bottlenecks and genetic drift; Effective population size; Small populations and rare alleles; The problem of inbreeding; Estimation of gene flow and metapopulation genetics; Hybridization and introgression; Outbreeding depression, Using genetic techniques to recover genetic diversity and population size in captive populations; Pedigree analysis and kinship; Captive breeding strategies

5. **The conservation of populations:** Basic population processes and small populations; Populations and metapopulations; Population viability analysis (PVA); PVA and the analysis of risk; Minimum viable populations and recovery strategies for threatened species; Invasive species and invasive process; Restoration of native populations eradicated by invaders

6. **The conservation of habitat and landscape:** Measurement of habitat use; Heterogeneity, Landscape gradients and patch dynamics; Problems of habitat loss, Isolation, and fragmentation; Edge effects; Managing habitat connectivity: The role of corridors in habitat conservation; Reserve design: algorithms, GAP analysis, Habitat suitability; Appropriate reserve size

7. **Policy and legal foundations of conservation biology:** Conservation law and policy in India; Common characteristics of effective national conservation law; The UN and its environmental programs dealing with conservation; International agencies and NGOs involved in conservation; Genetics forensics techniques to determine if laws and treaties are being obeyed

8. **Case studies:**Current case studies related to conservation biology: Project tiger, Project elephant

Suggested Readings

1. Hunter M.L, Gibbs JP (2007) Fundamentals of Conservation Biology. Malden: Blackwell
2. Hambler C (2004) Conservation. Cambridge University Press
3. Pullin AS (2002) Conservation Biology. Cambridge University Press
4. Sutherland W (2000) The Conservation Handbook-Research, Management and policy. Blackwell Science Ltd.
5. Van Dyke F (2008) Conservation Biology- Foundations, Concepts, Applications. Springer Science + Business Media B.V.
6. Ausden M (2010). Habitat management for conservation: A handbook of Techniques. Oxford Univ. Press.
7. PrimackRB (2008). A Primer of Conservation Biology. Sinauer Associates.
8. Primack RB. (2006). Essentials of Conservation Biology. 4th Edition. Sinauer Associate

ME209P. PRACTICALS BASED ON ME209 (1 Credits)

ME206M. ENVIRONMENTAL IMPACT ASSESSMENT (MINOR) (2 Credits)

1. **Origin and Scope of EIA:** Origin of Environmental Impact Assessment (EIA); Principles and scope; Indian policies regarding EIA; Developmental projects requiring EIA; ISO 14000

2. **Steps of EIA:** Screening; Scoping; Impact prediction; Consideration and comparison of alternatives; Stakeholder involvement; Compensatory actions and mitigation measures; Preparation of EIA report; Review and decision making

3. **Methods for EIA:** Methods for organizing and presenting information: Ad Hoc Method; Checklists; Scales and Weights, Matrices; Networks and overlay approaches; Simulation Modelling, Spatially Based Methods; Rapid Assessment, Risk and Uncertainty in EIA

4. **Approaches to impact prediction:** Physical, experimental, computer and mathematical Models; Predicting quantitative & qualitative environmental changes in components of environment

5. **EIA for developmental programmes:** EIA for various Industries; Urban development; Energy projects; EIA for resources management

6. **Strategic environmental assessment:** Aims, principles and scope of Strategic Environmental Assessment (SEA); Importance and limitations; Procedures; Comparison of SEA and EIA

7. **Socioeconomic impact analysis:** Aims, Principles and scope of Socioeconomic Impact Analysis (SIA), Basic steps in SIA, Analysis of public services and facilities impacts; Fiscal impact analysis

8. **Case Studies:** Current case studies related to environmental impact assessment such as Narmada Project, Valley of Flowers, Coal Mining Projects

Suggested Readings

1. Abaza H, Bisset R, Sadler B (2004) Environmental Impact Assessment and Strategic Environmental Assessment: Towards an Integrated Approach. UNEP, Geneva
2. Anjaneyulu Y, Manickam V (2011) Environmental Impact Assessment Methodologies. CRC Press
3. Eccleston CH (2017) Environmental Impact Assessment: A Guide to Best Professional Practices. CRC Press
4. Lawrence DP (2003) Environmental Impact Assessment: Practical Solutions to Recurrent problems. John Wiley & Sons, Inc., New Jersey.
5. Morgan RK Environmental Impact Assessment: A Methodological Approach. Springer US.
6. Mareddy AR, Shah A, Davergave N (2017) Environmental Impact Assessment: Theory and Practice. Butterworth-Heinemann Pub
7. Wood C (2014) Environmental Impact Assessment: A Comparative Review. Routledge
8. Glasson J, Therivel R, Chadwick A (2013) Introduction to Environmental Impact Assessment. Routledge,
9. Hanna KS (2015) Environmental Impact Assessment: Practice and Participation. Oxford University Press

ME207: SCIENCE COMMUNICATION (THEMATIC REVIEW & PRESENTATION) (1 Credit)

ME208: STUDY TOUR/EXPERIENTIAL LEARNING (2 credits)

THIRD SEMESTER

ME301. STATISTICAL METHODS (2 Credits)

1. **Data and its properties:** Types of data; Scales of measurement; Data distribution; Tabular and Graphical presentation of data

2. **Descriptive statistics:** Populations and Samples; The Frequency distribution; Measures of central tendency, dispersion and shape; The normal distribution and Central Limit Theorem; Confidence intervals for population mean; The standard score

3. **Student's t test:** The nature of t distributions; One-sample t-test; Two-sample t-test; Repeated measures t-test; Unequal variance t-test

4. **Analysis of variance:** Assumptions for use of the ANOVA; The nature of F distribution; The completely randomized design; The randomized complete block design; The repeated measures design; Factorial experiments; Multiple comparisons of means

5. **Chi-Square tests:** The nature of chi-square distributions; Goodness-of-fit tests; Contingency table analysis; Relative risks and odds ratios

6. **Correlation and regression:** Scatterplot; The Pearson product-moment correlation coefficient; The regression line; The accuracy of prediction; Assumptions underlying regression and correlation; The Coefficient of Determination; Multiple Regression; Multiple Correlation and Partial Correlation

7. **Nonparametric statistics:** Distribution-free Tests; The Sign Test; The Wilcoxon Rank Sum Test for Independent Samples; The Wilcoxon Signed Rank Test for the Paired Difference Experiment; The Kruskal–Wallis Test for a Completely Randomized Test; The Friedman Test for a Randomized Block Design; Spearman Rank Correlation Coefficient

8. **Case studies:** Statistical analysis of Varanasi Census and Climate data using Excel, SPSS and R

Suggested Readings

1. SokalRR, Rohlf JF (2009) Introduction to Biostatistics, 2nd Ed. Dover Publications, Inc., Mineola, New York.
2. Zar, JH (2009) Biostatistical Analysis, 5th Ed. Prentice Hall.
3. Reimann C, Filzmoser P et al. (2009) Statistical Data Analysis Explained: Applied Environmental Statistics With R. Wiley Online Library.
4. Weaver KF, Morales VC, Dunn SL, Godde K,Weaver PF(2018) An Introduction to Statistical Analysis in Research-With Applications in the Biological and Life Sciences. John Wiley & Sons, Inc.

ME301P. PRACTICALS BASED ON ME301 (1 Credit)

ME317. QUANTITATIVE ECOLOGY (2 Credits)

1. **Sampling methods**: Types of sampling units-fixed area, point intercept, line intercept, distance methods; Placement of sampling units-random, stratified random, regular, subjective; Number of sampling units; Measures of sample adequacy

2. **Data exploration and management:** Data screening for quality assurance; Outliers, transformations and standardisations; Planning; Creating data; Processing and documenting data; Preserving and sharing data; Reusing data

3. **Measures of species abundance and diversity:** Cover; Frequency; Biomass; Basal Area; Relative measures; Alpha, beta and gamma diversity; Evenness; Species area curves

4. **Measures of Association:** Association between sites-Q Analysis; Association among species-R Analysis; Similarity coefficients/distance measures

5. **Classification:** Normal Association Analysis; Types of classification; Divisive monothetic methods; Agglomerative polythetic methods; Divisive polythetic methods; Two-Way Indicator Species Analysis (TWINSPAN)

6. **Ordination:** Direct Gradient Analysis; Indirect Gradient Analysis; Polar and Non-polar ordination; Principal component analysis and redundancy analysis; Correspondence analysis and canonical correspondence analysis; discriminant analysis; Detrended Correspondence Analysis; Principal coordinate analysis and non-metric multidimensional scaling

7. **Structural Models:** Classification and regression trees; Structural Equation Modeling

8. **Case Studies:** Forest vegetation of Vindhyan highlands; Herbaceous diversity in different ecosystems of Varanasi

Suggested Readings

1. Causton DR (1988) An Introduction to Vegetation Analysis-Principles, Practice and Interpretation. Unwin Hyman, London
2. Zuur AK, Ieno EN, Smith GM (2007) Analysing Ecological Data. Springer
3. McCune, B. & Grace J.B. Analysis of Ecological Communities. MjM Software Design, Oregon.
4. British Ecological Society (2014) A Guide to Data Management in Ecology and Evolution
5. Mandallaz D (2007) Sampling Techniques for Forest Inventories; Chapman & Hall/CRC Press

ME317P. PRACTICALS BASED ON ME317 (1 Credit)

ME318. HUMAN ECOLOGY (2 Credits)

1. **Historical Account of Humans in the environment:** Human evolution; Hunter gatherers; The transition to agriculture; Industrial age and beyond

2. **Human Population:** Numbers of people; Birth and death rates; Growth rate; History of population growth; Social mechanisms of population regulation; Population structure and projection; Population and carrying capacity; Human migrations

3. **Humanity's Current Dilemma**: Human biomass appropriation; Climate change; Ozone shield rupture; Land use change and degradation; Biodiversity loss; Planetary boundaries; Ecological footprint; Poverty and its measures

4. **Human Food Security:** The agricultural sector and economic Growth; Agricultural Growth and Poverty Reduction; Measuring agricultural productivity and natural assets; Metrics for food insecurity and malnutrition; Approaches to achieving sustainable food security

5. **Urban Environment:** New adaptive problems in urban environments; Urbanization and alienation from nature; Coexistence of urban ecosystems with nature

6. **Cultural and Spiritual Ecology:** Local environments, cultural beliefs, and behaviour; The genesis of maladaptions in human cultural evolution; Common perceptions of nature; Attitudes of religions toward nature; Notions of Mother nature and the balance of nature; Traditional knowledge systems

7. **Ecological Economics:** History and development; Nature and ecology; Limits to growth; Tragedy of Commons; Sustainable development; Energy economics; Environmental services; Ecological-economic modelling; Ecosystem services; Ecological footprint

8. **Case Studies:** Current case studies related to human ecology; MDG indicators for India; Current human migration crisis

Suggested Readings

1. Kormondy EJ, Brown DE (1998) Fundamentals of Human Ecology. Prentice Hall, NJ
2. Marten GG(2001) Human Ecology- Basic Concepts for Sustainable Development. Earthscan Publications
3. Barr S(2006) Environment and Society: Sustainability, Policy and the Citizen. Ashgate Publishing Ltd. Hampshire, UK.
4. Common MS, Stagl S(2012) Ecological Economics: an Introduction. Cambridge Univ. Press, Cambridge
5. National Academies Committee on Food Security for All as a Sustainability Challenge Science and Technology for Sustainability Program Policy and Global Affairs (2012) A Sustainability Challenge: Food Security for All-Report of Two Workshops. National Academies Press, Washington, D.C.

ME318P. PRACTICALS BASED ON ME318 (1 Credit)

ME319. FOREST ECOLOGY (2 Credits)

1. **Forest resources**: Forest biomes of the World; Forest types of India; Historical perspectives on forest resource use; Control and management

2. **Natural forests:** Structure, metabolism and hydrology, dynamics and growth

3. **Plantation and urban forests:** Biology of plantation growth; Growth Rates and wood quality; Choosing the species and site; Establishment and plantation management; Importance of urban forests; Structure, functioning, planning and management of urban forests

4. **Forest inventories**: Forest mensuration; Sampling in forest surveys; Remote sensing, Geographic and Forest Information Systems; Field measurements for forest carbon monitoring

5. **Ecosystem goods and services from forests:** Economic valuation; Carbon sequestration in forest ecosystems

6. **Threat to the forests:** Pests and Diseases; Invasive species; Natural disasters; Fire; Land-use alteration; Pollution; Climate change

7. **Forest Conservation and Sustainable Management:** Criteria and Indicators for Sustainable Forest Management; Community based management of forest resources; Forest landscape conservation and restoration; Policy and legal framework for forest management-National forest policy, Indian Forest Act- 1927’ UN initiatives for forest management

8. **Case studies:** Forests of Corbett National Park; Forests of Vindhyan Highlands; Forests of Himalaya

Suggested Readings

1. Adrian NC (2007) Forest Ecology and Conservation: A Handbook of Techniques; Oxford University Press.
2. Leigh EG (1999) Tropical Forest Ecology; Oxford University Press.
3. Joe R. McBride (2017) The World's Urban Forests: History, Composition, Design, Function and Management; Springer International Publishing
4. Landsberg J, Waring R (2014) Forests in Our Changing World: New Principles for Conservation and Management; Island Press
5. Chao Li, Lafortezza R, Chen J (2011) Landscape Ecology in Forest Management and Conservation: Challenges and Solutions for Global Change; Springer
6. Bauhus J, van der Meer P, Kanninen M (2010) Ecosystem Goods and Services from Plantation Forests. Earthscan Publications Ltd
7. Mandallaz D (2007) Sampling Techniques for Forest Inventories; Chapman & Hall/CRC

ME319P. PRACTICALS BASED ON ME319 (1 Credit)

ME320. WETLAND ECOLOGY (2 Credits)

1. **Introduction:** Importance of wetlands;Wetland classification; Wetland inventories, Important wetlands of India

2. **Wetland Structure:** Wetland hydrology; Wetland Soils: structure, spatial and temporal patterns

3. **Plant Adaptations for Aquatic life:** Morphological, anatomical and physiological adaptations

4. **Wetland Metabolism:** Primary production; Litter decomposition; Food webs; Mineral cycling

5. **Community Dynamics in Wetlands:** Patterns and models of succession; The role of disturbance in community dynamics

6. **Ecosystem goods and services:** Economic valuation; Wetlands for water treatment

7. **Wetland degradation and Sustainable Management:** Wetland degradation: invasive species, pollution, eutrophication, climate change; Restoration of degraded wetlands; Legal and policy framework for wetland conservation; Ramsar Sites; Sustainable watershed and wetland management

8. **Case Studies:** Ganga; Chilka Lake; Dal Lake

Suggested Readings

1. Cronk JK, Siobhan M (2001) Wetland Plants: Biology and Ecology, Fennessy Publisher: CRC Press
2. Semeniuk C (2007) The Becher Wetlands - A Ramsar Site, Springer Publications
3. McKinstry CM, Hubert WA, Anderson SH (2004) Wetland and Riparian Areas of the Intermountain West: Ecology and Management, University of Texas Press
4. Westlake DF, Kvet J, Szczepanski A (2009) The Production Ecology of Wetlands: The IBP Synthesis; CRC Press
5. Tiner R.W (2017) Wetland Indicators: A Guide to Wetland Formation, Identification, Delineation, Classification, and Mapping, Second Edition; CRC Press
6. Aber J.S, Pavri F, Aber S.W (2012) Wetland environments: A Global Perspective; Wiley Blackwell

7. John Bavor H ,Vymazal J (2011) Water and Nutrient Management in Natural and Constructed Wetlands, Springer

ME320P. PRACTICALS BASED ON ME320 (1 Credit)

ME321. AGROECOLOGY (2 Credits)

1. **Agriculture and agroecology**: The importance of agriculture; Origin and development of agriculture; Agricultural expansion and tropical deforestation; Ecological impacts of modern agriculture; The agroecosystem concept; Energy flow and nutrient dynamics in agroecosystems; Population characteristics of crop, non-crop, and related natural species populations

2. **Biodiversity in agroecosystems:** Diversity and function of soil microbes and fauna; Importance of crop and livestock diversity; Diversity, resilience, and sustainability; Management of biodiversity in agroecosystems

3. **Water and nutrient use efficiency**: Water use and water-use efficiency; Variation in water-use efficiency within crop species; Water productivity in agriculture; Strategies to enhance water use efficiency of crops; Nutrient use efficiency; Major pathways of nutrient loss from cropping systems; Management to maximize nutrient use in agroecosystems

4. **Interactions in populations and communities:**Plant interactions; Interference in monocrops and multiple species stands; Interference in weed–crop systems; Allelopathy; Direct and indirect facilitation

5. **Coping with extreme meteorological events:** Impact of heat wave, drought and floods on agriculture, adaptation and mitigation strategies

6. **Global change and agriculture:** Agricultural greenhouse gases; Direct effects of rising atmospheric carbon dioxide and air pollutants on crop yields, Climate change and food security; Agricultural adaptations to climate change; Approaches for carbon sequestration in croplands

7. **Sustainable agriculture practices**: Components of sustainability measurement; Criteria for indicators selection; Indicators of agricultural sustainability; Principles and strategies for designing sustainable farming systems; Conservation and organic agriculture as an alternatives to conventional farming

8. **Case studies**: System of Rice Intensification (SRI); Zero-tillage systems; Organic farming systems

Suggested Readings

1. Brussaard L, Ferrera-Cerrato R (1997),Soil Ecology in Sustainable Agricultural Systems; CRC-Press
2. Titi AE (2002) Soil Tillage in Agroecosystems; CRS Press
3. Ryszkowski L (2001) Landscape Ecology in Agroecosystems Management (Advances in Agroecology); CRC Press
4. Collins WW, Qualset CO (1998) Biodiversity in Agroecosystems; CRC Press
5. Schutter O.D, Lichtfouse E (2012) Agroecology and Strategies for Climate Change; Springer Netherlands
6. Benkeblia N (2014) Agroecology, Ecosystems, and Sustainability;Taylor and Francis
7. Martin, Ralph C (2014) Managing Energy, Nutrients, and Pests in Organic Field Crops; CRC Press

8. Laladhas K.P, Nilayangode P, Oommen OV (2017) Biodiversity for Sustainable Development; Springer International Publishing

ME321P. PRACTICALS BASED ON ME321 (1 Credit)

ME322. URBAN ECOLOGY (2 Credits)

1. **The urban ecosystem**: Importance of cities, Global patterns; Impact of urbanization; Urban disaster risk; The dynamics of urban (eco)systems; Cities as human, ecological and hybrid ecosystems; Complexity, emergent properties, and self-organization; Resilience in urban ecosystems

2. **Humans as a component of ecosystems**: Emergence and evolution of settlement patterns; Modelling urban development and ecology; Modelling changes in land use and land cover; Population growth and the urban environment

3. **Urban patterns and ecosystem function**: Spatial patterns and mosaics; Processes and functions in urban ecosystems; Net primary productivity, hydrological function, nutrient cycles, biodiversity, disturbance regimes

4. **Atmospheric processes**: Urban air quality and climate change; Urban heat islands; Noise pollution

5. **Urban patch dynamics**: Globalization, political Change and urban development; Urban sprawl patterns; Measuring urban landscape patterns and environmental quality- research design and data collection in the urban setting; Analysis of urban growth and sprawl from remote sensing data; Ecological footprint measurement; Green city index

6. **Urban planning and governance**: Ecological landscape and planting design; Benefits and costs of urban forestry; wetlands and water bodies; Policies and legal instruments for urban governance

7. **Sustainable urban development:** The role of place in the urban socio-physical environment; A sustainable cities framework for housing; Transport planning for sustainable communities; Measuring urban sustainability; Social sustainability in urban areas; Adopting to climate change and natural disasters

8. **Case studies:** Urban ecology of New Delhi, Varanasi and Kyoto

Suggested Readings

1. Shulenberger E, Endlicher W, Alberti M, Bradley G, Ryan C, ZumBrunnen C, Simon U, Marzluff J(2008),Urban Ecology An International Perspective on the Interaction Between Humans and Nature; CRC Press
2. Alberti M (2008),Advances in Urban Ecology: Integrating Humans and Ecological Processes in Urban Ecosystems; CRC Press ISBN 0387755098
3. Forman RTT (2008) Urban Regions: Ecology and Planning Beyond the City; Cambridge University Press.
4. Carreiro MM, Song Y, Wu J (2007) Ecology, Planning, and Management of Urban Forests: International Perspective; Springer Publications
5. Ossola A, Niemelä J (2017) Urban Biodiversity: From Research to Practice. Routledge
6. Parris KM (2016) Ecology of Urban Environments. John Wiley & Sons
7. Forman RTT (2014) Urban Ecology: Science of Cities, Cambridge University Press

ME322P. PRACTICALS BASED ON ME322 (1 Credit)

ME323. LANDSCAPE ECOLOGY (2 Credits)

1. **The emergence of landscape ecology:** Intellectual roots of landscape ecology; Emerging concept of scale; Environmental security and landscape ecology; Landscape ecology theories

2. **Causes of landscape pattern:** Abiotic causes of landscape pattern; Biotic interactions, Human land use, Disturbance

3. **Landscape structure and dynamics:** Ecological organization of landscapes; Measurement and understanding of heterogeneity, fragmentation and connectedness; Land use and land cover change dynamics

4. **Ecological processes within landscapes:** Ecotones and edge effect; Metapopulations and landscape; Movement of multi-habitat species between landscape elements; Corridors and the functioning of metapopulations; Interspecific relationships and biodiversity in landscapes

5. **Geochemical flows in landscapes:** Buffer zones and nutrient retention; Erosion dynamics; Watershed level transfer of materials

6. **Quantification of landscape pattern:** Metrics for Quantifying Landscape Pattern; Geostatistics or Spatial Statistics; Remote sensing and GIS applications

7. **Landscape ecology applications:** Application of landscape ecology concepts to landscape management, design and nature conservation

8. **Case studies:** Tarai Arc landscape; Ganga river bank landscape; Coastal landscape

Suggested Readings

1. Dramstad W, Olson JD, Forman RTT (1996) Landscape Ecology Principles in Landscape Architecture and Land-Use Planning;Island Press
2. Kilgo J, Blake JI, Pulliam HR (2005) Ecology and management of a forested landscape: fifty years on the Savannah River Site; Island press
3. Gergel SE, Turner MG (2000) Learning landscape ecology: a practical guide to concepts and techniques; Springer Publications
4. Wiens JA, Moss MR (2005) Issues and Perspectives in Landscape Ecology;Cambridge University Press
5. Hilty J, Lidicker Jr. WZ, Merenlender A (2006) Corridor Ecology: The Science and Practice of Linking Landscapes for Biodiversity Conservation; CRC Press
6. E. Gergel S, Turner M.G (2017) Learning Landscape Ecology: A Practical Guide to Concepts and Techniques; Springer-Verlag New York
7. Turner M.G ,Gardner R.H (2015)Landscape Ecology in Theory and Practice: Pattern and Process; Springer-Verlag New York

ME323P. PRACTICALS BASED ON ME323 (1 Credit)

ME324. MOLECULAR ECOLOGY (2 Credits)

1. **Emergence of molecular ecology:** Concept and principles of molecular ecology; Molecular environment and molecular landscapes; Molecular genetics: mutation and recombination, polymerase chain reaction, primers, DNA sequencing, second and next generation sequencing; Single cell genomics

2. **Molecular markers in ecology:** Modes of inheritance; Co-dominant markers: Allozymes, Restriction Fragment Length Polymorphism (RFLPs), DNA sequences, Single nucleotide polymorphisms (SNPs), Microsatellites; Dominant markers: Random Amplified Polymorphic DNA (RAPDs), Amplified Fragment Length Polymorphism (AFLPs)

3. **Genetic analysis of populations:** Population; Quantifying genetic diversity: Hardy–Weinberg equilibrium, estimates of genetic diversity, choice of marker; Factors influencing genetic diversity: genetic drift, effective population size, founder effects an invasive species, natural selection, reproduction

4. **Genetic analysis of multiple populations:** Multiple populations; Quantifying population subdivision: genetic distance, F-statistics; Quantifying gene flow: direct and indirect methods; Population differentiation: gene flow and genetic drift, gene flow and local adaptation

5. **Ecogenomics:** Mapping of ecologically important traits; cDNA libraries and ESTs; Microarrays and genotyping; Reverse genetics; QTL mapping; Soil microbial diversity: microbial functions in soil, soil metagenome; Plant-microbe and microbe-microbe interactions

6. **Phylogeography:** Phylogepgraphy; Molecular markers in phylogeography; Molecular clocks; Bifurcating Trees; The coalescent; Nested Clade phylogeographic analysis and statistical phylogeography; The distributions of genetic lineages; Comparative phylogeography; Allele sharing between species

7. **Conservation genetics:** The need for conservation; Molecular taxonomy: species concepts, DNA barcoding, subspecies, hybrids; Population size, genetic diversity and inbreeding: translocations, captive breeding, genetic diversity banks

8. **Case studies:** Applications of molecular ecology in sustainable agriculture; ecological restoration, bioremediation

Suggested Readings

1. Rowe G, Sweet M (2017) An Introduction to Molecular Ecology edited by Beebe Oxford University Press.
2. Freeland JR, Kirk H, Petersen S (2011) Molecular Ecology, Second Edition. John Wiley & Sons Ltd.
3. DeSalle R, Schierwater B (1998) Molecular Approaches to Ecology and Evolution, Springer.
4. de Bruijn FJ (2011) Handbook of Molecular Ecology (Vol I –II), John Wiley & Sons Ltd.
5. van Straalen, N. M., and D. Roelofs. 2012. An Introduction to Ecological Genomics. Oxford University Press, New York
6. Rowe G, Sweet M(2017) An Introduction to Molecular Ecology;Oxford University Press
7. Bruijn F.J.D (2011) Handbook of Molecular Microbial Ecology I: Metagenomics and Complementary Approaches; Wiley-Blackwell

ME324P. PRACTICALS BASED ON ME324 (1 Credit)

ME325.SOIL ECOLOGY (2 Credits)

1. **Soil as a life supporting system:** Soil as a natural, dynamic, functioning body;Soil as a life supporting system; Soil as three phase disperse system; Pedogenesis and profile development; Soil structure and properties; Soil heterogeneity: taxonomy and mapping

2. **Soil biodiversity:** Soil organisms: taxonomy, limiting factors & habitat structure; Bacteria; Fungi; Protozoans; Nematodes; Earthworms; Mites; Arachnids; Myriapods and isopods; Insects; Non-insect hexapods; Vertebrates; Managing soil bio-diversity

3. **Soil ecological functions and ecosystem services:** Soil community dynamics; Soil food chain & food web; Primary and secondary production in soils; Soil organic matter: accumulation and decomposition; Energy & material flows in soil; Value of soil system: soil ecosystem services for good quality of life and human well-being; SDGs and soil system

4. **Soil interactions:** Influences of plants on soil processes; Water retention and movement in soil; Soil nutrient availability and plant community composition; Rhizospheric interactions: plant-microbe and microbe-microbe interactions; Aboveground-belowground interactions

5. **Soil degradation:** Drivers of soil degradation: flood, drought, fire, soil erosion, industrial pollution, waste disposal, intensive agriculture, invasive alien species, unscientific land use practices; Extent of soil degradation; Identification and mapping: Indicators for soil degradation

6. **Soil system & climate change:** Soil as a sink and source of greenhouse gases; Effect of changing climate on physical chemical and biochemical properties of soil; Soil microbial diversity and climate change; Soil interactions and climate change; Soil ecosystem services and climate change

7. **Adaptive soil management:** Principles of adaptive soil management; Integrated watershed approaches: agronomic practices, irrigation and drainage management, nutrient and organic matter management; Restoration of polluted soil: physical, chemical and biological methods; Role of Remote Sensing & GIS in soil management; Stakeholder involvement; National and International initiatives

8. **Case studies:** Caste studies on soil resource management

Suggested readings

1. Bardgett R(2005) The Biology of Soil: A Community and Ecosystem Approach. Oxford University Press, Oxford
2. Rakshit A, Abhilash PC. Sarkar A, Singh HB (2017) Adaptive soil management: From theory to practice. Springer
3. Tan KH (2009) Environmental Soil Science, CRC Press.
4. Coleman DC, Crossley DA, Hendrix PF (2007) Fundamentals of Soil Ecology. Elsevier/Academic Press, Amsterdam.
5. Coleman DC, Callaham MA, Crossley DA (2017)Fundamentals of Soil Ecology. Academic Press
6. Lukac M, Grenni P, Gamboni M (2017) Soil Biological Communities and Ecosystem Resilience. Springer
7. Paul EA (2014) Soil Microbiology, Ecology and Biochemistry. Academic Press
8. Wall DH, Bardgett RD, Behan-Pelletier V, Herrick JE, Jones TH, Strong DR (2013) Soil Ecology and Ecosystem Services. Oxford University Press

ME325P. PRACTICALS BASED ON ME325 (1 Credit)

ME326. RESTORATION ECOLOGY (2 Credits)

1. **Introduction to restoration ecology:** The science of restoration; Ecological principles in restoration ecology; Goal setting for ecological restoration; Setting restoration objectives

2. **Ecology of disturbed and degraded ecosystems:** Definition of disturbances; Disturbances agents; Classification of disturbances; Ecological degradation; Characteristics of degraded ecosystems; Invasive species biology & control

3. **Ecological principles for restoration:** Ecological succession; Manipulating successional trajectories; Ecological assembly rules; Genetics and population dynamics; Habitat fragmentation; landscape connectivity and biological corridor

4. **Restoration project management:** Planning for restoration; Monitoring and assessment techniques; Attributes of restored ecosystems, reference conditions, range of variability; Evaluating restoration success; Landscape management techniques:Fire, grazing, planting methods, nursery operations

5. **Restoration of terrestrial ecosystems:** Forest, grasslands and savanna restoration; Restoration of degraded soils; Biodiversity restoration

6. **Restoration of aquatic ecosystems:** Watershed planning & assessments; Watershed, wetlands and river restoration

7. **Sustainable restoration practices:** Principles of good ecological restoration practices; Ethics in restoration ecology; Sustainability & ecological design; Community involvement in restoration

8. **Case studies:** Current case studies related to restoration ecology

Suggested Readings

1. Bainbridge DA (2007) A guide for desert and dryland restoration. Island Press
2. Jordan WR, et al. (1987) Restoration ecology. Cambridge University Press
3. Falk DA, et al. (2006) Foundations of restoration ecology: the science and practice of ecological restoration. Society for Ecological Restoration International
4. Clewell AF, Aronson J (2007) Ecological Restoration: Principles, Values, and Structure of an Emerging Profession. Island Press
5. Doyle M, Drew CA (eds.) (2008) Large-Scale Ecosystem Restoration. Island Press
6. Palmer M.A, Zedler J.B, Falk D.A(2016) Foundations of Restoration Ecology; Island Press
7. Ilan C , Martin F,Jennifer H (2015)Land Restoration: Reclaiming Landscapes for a Sustainable Future; Academic Press

ME326P. PRACTICALS BASED ON ME326 (1 Credit)

ME327. ECOLOGICAL MODELLING (2 Credits)

1. **Introduction**: What is a model? Why do we need Models? Modelling steps and ingredients; The modeller's toolkit

2. **Model formulation**: Conceptual model; Mathematical formulations; Formulation of chemical reactions; Enzymatic reactions; Basic formulation of ecological interactions; Coupled model equations; Model simplifications; Impact of physical conditions

3. **Spatial components and transport:** Microscopic and macroscopic models; Representing space in models; Transport in a zero-dimensional model; Transport in a one-dimensional model; Boundary conditions in spatially explicit models

4. **Parameterization:** In situ measurement; Literature-derived parameters; Calibration

5. **Model solution:** Analytical methods; Numerical methods

6. **Stability and steady-state**: Stability of one first-order differential equation; Stability of two differential equations; Multiple; steady-State solution of differential equations; Formal analysis of stability; Limit cycles

7. **Testing and validating the model:** Testing the correctness of the model solution; Testing the internal logic of the model; Model verification and validity; Model sensitivity

8. **Case Studies:** Model examples for eutrophication, carbon and nitrogen dynamics

Suggested Readings

1. SoetaertK, Herman PMJ(2009) A Practical Guide to Ecological Modelling-Using R as a Simulation Platform. Springer
2. Gillman M (2009) An Introduction to Mathematical Models in Ecology and Evolution-Time and Space. 2nd Edition. Wiley-Blackwell
3. Jørgensen SE, Bendoricchio G (2001) Fundamentals of Ecological Modelling. Elsevier
4. Ellis M, Liu J,Christofides PD (2017) Economic Model Predictive Control: Theory, Formulations and Chemical Process Applications; Springer International Publishing
5. Jørgensen S.E (2016) Ecological Model Types; Elsevier
6. Jordán F, Jørgensen SE (2012) Models of the Ecological Hierarchy: From Molecules to the Ecosphere; Academic Press
7. Breckling B , Jopp F, Reuter H, Jopp F, Reuter H,Breckling B (2011) Modelling Complex Ecological Dynamics:An Introduction into Ecological Modelling for Students, Teachers & Scientists; Springer-Verlag Berlin Heidelberg

ME327P. PRACTICALS BASED ON ME327 (1 Credit)

ME328.BIODIVERSITY MANAGEMENT (2 Credits)

1. **Understanding biodiversity:** Defining Biodiversity; Biodiversity and the definition of species; Implications of the species concept in conservation; Niche assembly theories and the unified neutral theory of biodiversity

2. **Biodiversity patterns in time and space:** Biodiversity and mass extinctions in geological time; Global biodiversity patterns; Current losses of biodiversity; Species vulnerable to extinction; Biodiversity hotspots; IUCN Red data Book

3. **Valuing biodiversity:** Valuing biodiversity and its contribution to ecosystem services; Social valuation of biodiversity: biodiversity for good quality of life and human well-being; Techniques for data collection and analysis of biodiversity use; SDGs and biodiversity

4. **Mapping, inventorying and monitoring biodiversity:** Types of biodiversity and its measurement; Diversity indices; Biodiversity assessment techniques; Documenting rarities and extinctions; Collecting specimens; Habitat mapping; Use of Remote Sensing & Geographical Information System for biodiversity monitoring and assessment; Biodiversity databases; Criteria and approaches to biodiversity monitoring

5. **Sustainable biodiversity conservation and management:** Current global prioritization strategies for biodiversity conservation; Sustainable use versus sustained yield; Distribution and protection of conservation priority areas; *In-situ* and *Ex-situ* conservation approaches;

Integrating sustainable development and conservation through benefit sharing, participatory approach and stakeholder involvement

6. **Methods for integrated conservation development projects:** Use of problem trees & objective trees, options analysis, Logical framework analysis, Risk analysis and stakeholder participation matrix in sustainable biodiversity management; Implementing management for long-term sustainability

7. **Biodiversity conservation initiatives:** National and international programmes and conventions for biodiversity conservation; Indian Forest Act (1927); Wildlife (Protection) Act (1972); Forest (Conservation) Act (1980); The Biological Diversity Act (2002); National Biodiversity Authority of India; National Biodiversity Action Plan of India

8. **Case Studies:** Management of biosphere reserves and Ramsar sites in India; Project tiger and Project Elephant; Biodiversity conservation plan for mining areas

Suggested Readings

1. Jeffries MJ (2006) Biodiversity and Conservation (Second edition). Rutledge
2. Sutherland W (2000) The conservation handbook-research, management and policy. Blackwell Science Ltd
3. Milner-Gulland, EJ, Rowcliffe M (2007) Conservation and Sustainable Use: A Handbook of Techniques. Oxford University Press
4. Weddell BJ (2002 Conserving living natural resources: In the context of a changing world. Cambridge, U.K: Cambridge University Press
5. Ausden M (2010) Habitat management for conservation: A handbook of techniques. Oxford Univ. Press
6. Laladhas KP, Nilayangode PV, Oommen O (2017) Biodiversity for Sustainable Development; Springer International Publishing
7. Khorshid AZ, Abid AA, Singh GS, Naeem M (2017)Plant biodiversity: monitoring, assessment and conservation; CABI

ME328P. PRACTICALS BASED ON ME328 (1 Credit)

ME329. GLOBAL CHANGE ECOLOGY (2 Credits)

1. **Introduction to global change:** Earth as a changing planet: global climate and ecological changes; Natural and human drivers of changes: natural hazards, land use land cover changes, pollution, biotic invasion, wildfire etc.; Changing atmospheric chemistry: rising tropospheric O_3, SO_2 and GHGs concentration

2. **Past major global changes:** The five major mass extinctions: Causes and impact of extinction events; Lessons learned from the past: climate as the common factor in major extinctions

3. **The impact of global changes on ecosystem structure and function:** Ecological indicators for global change: changes in species range and distribution, changes in timing and processes: phenology; Changes in tropical, temperate, glacier and snowpack dependent and marine ecosystems; Global change effects on biogeochemical and hydrologic cycling

4. **Impact of global change on ecosystem services & human wellbeing:** Impact of global change on provisioning, supportive, regulatory and cultural services of various ecosystems; Good quality of life and human-wellbeing under changing environment

5. **Ecological feedback on global change:** Ecological adaptations and evolutionary processes; Mechanisms of species and ecosystem resilience: Genotypic and phenotypic adaption strategies, changes in species and functional composition

6. **Modelling species and ecosystem response to global change:** Dynamic global vegetation models; Species distribution models; Gap models; Models for aquatic and marine systems; Earth system models for predicting integrated impacts

7. **Nature based adaptation strategies:** Protected areas for climate change; Connectivity and landscape management; Manging species threatened by global change; Biological methods for reducing greenhouse gases; National and international climate policies

8. **Case studies:** Case studies and success stories.

Suggested readings

1. Hannah L (2010) Climate change biology, First Edition Academic Press.
2. Hannah L (2014) Climate change biology, Second Edition Academic Press.
3. Newman JA (2011) Climate change biology, CABI
4. Goudie AS (2002) Encyclopaedia of Global Change: Environmental Change & Hyman Society, Vol I, Oxford University Press
5. Goudie AS (2002) Encyclopaedia of Global Change: Environmental Change & Hyman Society, Vol II, Oxford University Press
6. Robinson-Easley CA (2017)Leadership for Global Systemic Change: Beyond Ethics and Social Responsibility; Palgrave Macmillan
7. Hertel TW, Baldos ULC (2016) Global Change and the Challenges of Sustainably Feeding a Growing Planet, Springer

ME329P. PRACTICALS BASED ON ME329 (1 Credit)

ME330. INDUSTRIAL ECOLOGY (2 Credits)

1. **Frameworks of industrial ecology:** Definition, goals, state of the industrial environment; Population and carrying capacity; Industrial production and consumption patterns; Ecological foot prints of industries

2. **Material and energy flow in industrial system:** Industrial metabolism; Material flow analysis; Anthropogenic vs natural fluxes of metals and metalloids; Energy flow analysis: primary energy feedstock, energy conversion process; Combustion and pre-combustion; Emission factors

3. **Life Cycle Assessment:** Life cycle interpretation; Inventory analysis and input/output techniques; Processes level LCA vs. economic input-output (EIO) LCA; Life cycle impact assessment (LCIA)

4. **Sustainable production strategies:** Cleaner production technologies**;** Product life extension; Material oriented strategies; Process oriented strategies; Distribution oriented strategies

5. **Sustainable waste management strategies:** Generation of solid, liquid and gaseous wastes; Sustainable waste management strategies: remanufacturing, recycling, resource recovery, landfill disposal.

6. **Managing industrial hazards:** Human health impacts of various industrial operations; Human health management; Occupational health management; Hazard management strategies

7. **Green belt designing:** Role of green belt in industrial systems; Selection of trees and green belt designing; Compensatory forestry

8. **Case studies:** Case studies and success stories

Suggested Readings

1. Graedel TE (2002) Industrial Ecology, 2nd Edition, Prentice Hall
2. Bourg D, Erkma S (2003) Perspectives on Industrial Ecology, Greenleaf
3. Manahan SE (1999) Industrial Ecology: Environmental Chemistry and Hazardous Waste, Lewis
4. Socolow R, Andrews C, Berkout F, Thomas V (1994) Industrial Ecology and Global Change, Cambridge University Press
5. Erkman S, Ramaswamy R (2003) Applied Industrial Ecology, Aicra Publishers
6. Ryan DR, Kumar G, Louis T (2017) Pollution Prevention: Sustainability, Industrial Ecology, and Green Engineering, Second Edition; CRC Press
7. Tatiya RR (2010) Elements of Industrial Hazards: Health, Safety, Environment and Loss Prevention; CRC Press

ME330P. PRACTICALS BASED ON ME330 (1 Credit)

ME331. ECOLOGICAL ECONOMICS (2 Credits)

1. **Principles of ecological economics:** Linkages between ecology, environment and socio-economic systems; Material balance approach: linear versus circular economy; Inter and intra-generational equity; Limits to growth; Sustainable development; Environmental Kuznets Curve.

2. **Ecological system & production:** Natural resourcesas a factor of production; Goods and services provided by the sustaining system; Ecological and environmental impacts of production; Improving the environmental performance of production

3. **Welfare Economics**: Pareto optimality and competitive equilibrium: Theories of externality and public goods, Coase's theorem, Property rights and transaction costs; Free Rider's problem, Optimal provision of public goods; Lindahl's equilibrium; Land use: Deforestation, Urbanization and their impact on environment; Air and water pollution; Pigovian tax and subsidy on pollution Control

4. **Demand & supply:** Ecological relationships and interactions of demand and supply: utility and elasticity, indifference curve; Market mechanism and environment: perfect competition, Imperfect competition and Monopoly; Negative externalities; Public policy failure; Government interventions;

5. **Property Regimes:** Common & private property; Common property resource and issues in global environmental resources sharing: the tragedy of the commons; Applications of fundamental economic theories in property management: Prisoners' Dilemma (PD) game, Olson's theory of collective action

6. **Ecosystem valuation:** Types of ecosystem services and its valuation; Valuation techniques: market and non-market, Scientific, behavioral and technological, production based, contingent valuation, Hedonic-pricing, travel cost method; Evaluation of ecological and environmental damages and benefits: cost benefit analysis (CBA); ecological impact assessment (EIA); social impact assessment (SIA)

7. **Resource Economics:** Ecological foot printing**;** Ecologically benign resource exploitation and consumption; Resource pricing techniques; Economic instruments for environmental protection: polluter pays principles, incentives and subsidies, green taxes, carbon tax, cap and trade

8. **Case studies:** Case studies and success stories

Suggested Readings

1. Daly HE, Farley J (2003) Ecological economics: principles and applications. Island Press, Washington, DC.
2. Brekke KA, Howarth RB (2002) Status, Growth, and the Environment: Goods as Symbols in Applied Welfare Economics, Edward Elgar
3. Brown LR (2001) Eco-Economy: Building an Economy for the Earth. New York: W. W. Norton
4. Bollier D (2002) Silent Theft: The Private Plunder of Our Common Wealth. New York: Routledge
5. Bhattacharya RN (2001) Environmental Economics: An Indian perspectives, Oxford University Press
6. Kumar P (2007)Economics of Environment and Development. CRC Press
7. Dumbrell AJ, Kordas RL,Woodward G (2016) Large-Scale Ecology: Model Systems to Global Perspectives; Academic Press
8. Patil GP, Gore SD, Taillie C (2011)Composite Sampling: A Novel Method to Accomplish Observational Economy in Environmental Studies; Springer

ME331P. PRACTICALS BASED ON ME331 (1 Credit)

FOURTH SEMESTER

ME401. DISSERTATION/THESIS WORK **(8 Credits)**

ME402.PRESENTATION **(2 Credits)**

(C) M.Sc. Environmental Sciences (Environmental Biotechnology)

FIRST SEMESTER

ME101. FUNDAMENTALS OF EARTH SYSTEM SCIENCE (2 Credits)

1. **The Earth and the solar system:** The solar system; Kepler's laws of planetary motion; Geological Time Scale; Age of the Earth; Basic principles of stratigraphy; Earth's gravity and thermal structure: geoid, spheroid; Isostasy

2. **Evolution of the Earth:** Modern theories on the origin of the Earth and other planetary bodies; Evolution of earth's atmosphere and oceans; Theories about the origin of life and the nature of fossil record: Earth's interior; Continental drift; Plate tectonics: mountain building; Volcanism; Earthquakes and Tsunamis

3. **Lithosphere:** Gross composition and physical properties of important minerals and rocks: properties and processes responsible for mineral concentrations; Nature and distribution of rocks and minerals in the earth and different parts of India; Genesis, classification and distribution of soils

4. **Atmosphere:** Vertical structure of atmosphere; Lapse rate, stability; Energy flow: conduction, convection, sensible and latent heat; Energy balance: radiation, absorption, scattering; Greenhouse gases and global warming; Radiative forcing, atmospheric boundary layer, dispersion of pollutants

5. **Hydro-and cryosphere:** Cryosphere; Fresh water and marine ecosystem; Oceanic heat and salinity balance; Ocean currents; Marine food and economic resources; Biological productivity of the oceans

6. **Atmospheric physics and chemistry:** Sources of trace gases and particulates in the atmosphere; Key processes in atmospheric chemistry: oxidation chemistry, halogen chemistry; Properties of aerosols, role and measurements; Ozone depletion; Clouds formation, cloud microphysical processes; Artificial rainmaking

7. **Earth's climate:** Classification of climate: Koppen's and Thornthwaite's scheme of classification; Ocean and climate; Atmosperic and ocean circulation; Genesis and characteristics of ENSO, El-Nino, ENSO and Indian monsoon; Climate modelling; Climate change and its impact; Climate change policy

8. **Case studies:** Case studies and success stories

Suggested Readings

1. CN Hewitt, AV Jackson (2009) Atmospheric Science for Environmental Scientists. Blackwell
2. JH Seinfeld, SN Pandis (2016) Atmospheric Chemistry and Physics. Wiley
3. SE Manahan (2010) Environmental Chemistry. Wiley
4. SE Cornell, IC Prentice, JI House, CJ Downy (2012). Understanding the Earth System - Global Change Science for Application. Cambridge
5. J Marshall, RA Plumb (2008). Atmosphere, Ocean and Climate Dynamics: An introductory Text. Elsevier
6. BJ Skinner, SC Porter, DB Botkin (2011). The Blue Planet: An Introduction to Earth System Science. Willey

ME101P. PRACTICALS BASED ON ME101 (1 Credit)

ME102. FUNDAMENTALS OF ECOLOGICAL SCIENCES (2 Credits)

1. **The scope of ecology:** The science of ecology; Historical development of ecological thoughts; Organization levels of ecological systems; Linking ecology and environmental issues

2. **The environment:** Biotic and abiotic environment and its interactions; Concept of limiting factors; Ecological adaptations; Habitat and niche concept

3. **Population ecology:** Population characteristics; Metapopulations; Population growth models; Concept of biotic potential and carrying capacity; Life history models (*r*&*K* selection); Factors regulating population growth

4. **Community ecology:** Nature of communities; Community interactions; Community structure and attributes; Species diversity and dominance

5. **Ecosystem ecology:** Ecosystem structure; Energy flow; Trophic levels; Food chains; Ecological pyramids; Ecological efficiencies; Trophic cascades; Ecosystem production, decomposition, Biogeochemical cycle of C, N and P; Nutrient cycling at ecosystem level

6. **Ecological succession:** Types; Mechanisms; Concept of climax; Steady state and stability in ecological systems; Ecosystem trends during succession

7. **Biogeography:** General features of major terrestrial and aquatic biomes; Theory of island biogeography; Biogeographical zones of India; Forest and grassland types of India

8. **Case studies:** Current case studies related to ecology; Dry tropical forests of India; Ecology of River Ganga

Suggested Readings

1. Odum EP, Barrett GW (2004) Fundamentals of Ecology (5th ed.). Brooks/ Cole Publishers
2. Krebs C (2009) Ecology: the experimental analysis of distribution and abundance (6th ed.). Pearson Benjamin Cummings, San Francisco.
3. Jørgensen SE (2010) Global Ecology (1st ed.) Academic Press
4. Stiling PD (2011) Ecology: Global Insights and Investigations. McGraw-Hill Education
5. Begon M, Howarth RW, Townsend CR (2014) Essentials of Ecology (4th ed.). Wiley
6. Velland M (2016**)** The Theory of Ecological Communities (MPB-57) (Monographs in Population Biology). Princeton University Press
7. Lawrence F (2017) Ecosystem Functioning & Restoration. Callisto Reference

ME102P: PRASCTICALS BASED ON ME102 (I Credit)

ME103. FUNDAMENTALS OF ENVIRONMENTAL BIOTECHNOLOGY (2 Credits)

1. **Introduction to biotechnology:** Historical Perspectives; Modern and old biotechnology; Biotechnology an interdisciplinary pursuit; Scope and future of environmental biotechnology

2. **Systems of molecular biology**: General organization of genetic material in prokaryotes and eukaryotes; Replication of genetic material; Gene and genetic code, transcription and translation, protein synthesis

3. **Techniques in biotechnology:** Biotechnology and its tools; Isolation and purification of genomic and plasmid DNA, RNA and protein; Electrophoresis; Polymerase chain reaction (PCR); Recombinant DNA techniques

4. **Basics of omics:** Concept and methods of genome, proteome, trancriptome and metabolome

5. **Basics of bioinformatics:** Application of information technology in biotechnology

6. **Biotechnology in environment:** Waste water and sewage treatment; Biofuels; Bioremediation: bioaugumentation, biotransformation, bioaccumulation; Biofertilizers; Biopesticides; Biological control in food security and biosafety

7. **Biotechnology in medicine:** Antibiotics; Vaccines; Gene therapy; Bio-pharmaceuticals; Bioreactors

8. **Case Studies:** Classical and emerging issues of environmental biotechnology

Suggested Readings

1. Young MM (2011) Comprehensive Biotechnology. Second edition, Elsevier
2. Evans G, Furlong JC (2010) Environmental biotechnology: Theory and application. Oxford: Wiley-Blackwell
3. Fulekar MH (2010) Environmental biotechnology. Science Publishers
4. Jordening HJ, Winter J (2005) Environmental biotechnology: Concepts and applications. Wiley-VCH
5. Rittmann BE, McCarty PL (2001) Environmental biotechnology: Principles and applications. McGraw-Hill
6. Scragg AH (2005) Environmental biotechnology. Oxford University Press
7. Vallero D (2010) Environmental Biotechnology: A Biosystems Approach. Elsevier

ME103P. PRACTICALS BASED ON ME103 (1 Credit)

ANY ONE PAPER AS PER THE CHOICE BASED CREDIT SYSTEM (2 Credit)

ME109. BIOCHEMISTRY (2 Credits)

1. **Water and energy:** Physical and chemical properties of water; Free energy, laws of thermodynamics; Role of high energy compounds in metabolism, metabolic pathways (anabolism, catabolism).

2. **Nucleic acids:** Introduction, classification, structure and biological function of nucleic acids; Chromosome organization and functions in eukaryotes; Process of transcription and translation

3. **Carbohydrates and proteins:** Introduction, structure, classification and biological functions of: Carbohydrates; Proteins; Ramchandran plot; Protein denaturation and folding

4. **Carbohydrate metabolism:** Biosynthesis and oxidation of carbohydrates and pathways involved; Anaerobic respiration; Fermentation

5. **Protein metabolism:** Biosynthesis and catabolism of proteins; Reactions involved in the metabolism of amino acids; Amino acid oxidation

6. **Lipids:** Lipids: Simple, derived lipids, compound lipids, fatty acids, oxidation of fatty acids; Biosynthesis of lipids

7. **Enzymes:** Introduction, structure and classification of enzymes, IUB nomenclature, EC numbers, enzyme specifictity, regulatory enzymes- allosteric enzymes, and kinetics

8. **Photosynthesis:** Bacterial Photosynthesis, oxygenic and anoxygenic; Central photochemical events, carbon dioxide fixation; Pigments and storage materials

Suggested Readings

1. Nelson DL, Cox MM (2017) Lehninger: Principles of Biochemistry. 7th edition, W H Freeman publishers
2. Rodwell VW, Bender DA, Botham KM, Kennelly PJ, Weil PA (2015) Harper's Illustrated Biochemistry (30th edition) Lange/McGraw Hill publishers
3. Voet D, Voet JG, Pratt CW (2016) Biochemistry, 5th edition, Wiley publishers
4. Satyanarayana U (2013) Biochemistry, 4th edition, Elsevier India
5. Berg JM, Tymoczko JL, Stryer L (2002) Biochemistry 5th edition, WH Freeman
6. Devlin TM, (2010) Textbook of Biochemistry with Clinical Correlations, 7th Edition, Wiley
7. Zubay, GL (1999) Biochemistry, McMillan publishers

ME109P. PRACTICALS BASED ON ME109 (1 Credit)

ME106M. ENVIRONMENTAL LAWS& POLICIES (MINOR) (2 Credits)

1. **Environmental protection in India**: Historical and modern mechanisms for environmental protection in India; Rules and regulations of central and state Government for environmental protection; Common law remedies

2. **National policy on environment:** National Committee on Environment and Planning (NCEP); National forest policy; National water policy; National energy policy; National wetland policy

3. **Constitutional provisions for environmental protection:** Constitutional provisions for environmental protections: fundamental duties of citizen and directive principles of state policy; Writ provisions for the protection of environment

4. **National environmental Acts:** The Water (Prevention and Control of Pollution) Act, 1974; The Air (Prevention and Control of Pollution) Act, 1981; The Environment (Protection) Act, 1986; Mining Act, 1952; Factories Act; Motor Vehicle Act; Hazardous Waste legislation for pollution abatement; Hospital Waste Management

5. **National legislations on forest and wildlife:** The Forest (conservation) Act, 1980; The Wildlife (Protection) Act, 1972; The Biological Diversity (Protection) Act, 2002: aims, objectives and major contents; The Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006

6. **Environmental legislations related to coastal zones:** Ambit and applicability of coastal regulation zone (CRZ) rules; Marine protected areas

7. **Institutional mechanisms for environmental protection:** Jurisdiction of High Courts, Supreme Court and Green Tribunal; Public interest litigation (PIL); Duties and functions of MoEF & CC; CPCB and SPCBs; NGT

8. **International environmental laws and treaties:** International agreements, conventions, treaties related to environment and sustainable development; Environmental quality and transboundary issues; Role of international agencies on environmental protection

Suggested Readings

1. Salzman J, Thompson Jr. B (2017) Environmental Law and Policy (Concepts and Insights) 3rd Edition, Foundation Press
2. Doabia TS (2017) Environmental and Pollution Laws in India, Vol I, LexisNexis
3. Doabia TS (2017) Environmental and Pollution Laws in India, Vol II, LexisNexis
4. Reddy KV (2013) Environmental Law, Asia Law House
5. Naseem M, Naseem S (2014) Environmental Laws in India (2nd Edition), Wolters Kluwer Law & Business

ME107M. SUSTAINABILITY SCIENCE (MINOR) (2 Credits)

1. **Foundations & history:** The emergence of sustainable development: its formative ideas and roots in development and environment debates; Key concepts and principles; The system dynamics of a finite planet; Basic thermodynamic and material laws and principles; Resource scarcity and carrying capacities

2. **Environmental justice:** The problem of allocation in the context of limits; The concept of environmental space and environmental inequality; Inter- and intra-generational justice; Contraction and convergence; Human rights to a safe environment

3. **Sustainable materials, technology and design:** The transformation of production process, infrastructures and systems; Concepts of resource efficiency, dematerialization, decoupling, clean or sustainable technologies, design for the environment, design for sustainability; Industrial ecology; Life cycle analysis

4. **Consumption, lifestyle & communication:** Getting to grips with the complexity of consumption and lifestyle; understanding people's motivations, attitudes, values and behaviours; The dynamics of transition and social change; The importance of gender issues in sustainable development

5. **Governance for sustainability:** Basic framing of the problem of governing common pool resources; history of governance, the social contract, 'governmentality'; Policy responses to sustainability; Agenda 21, UN SDGs

6. **The good life, development & wellbeing:** Wellbeing, quality of life and sustainability; sustainability as capabilities for flourishing within ecological limits; Philosophical and ethical dimensions of sustainable development

7. **Measuring sustainability:** Sustainability indicators; Research methods and reporting: tools, statistics and accounting

8. **Case studies:**Current case studies related to sustainability science

Suggested Readings

1. Daly HE (1996) Beyond Growth: the Economics of Sustainable Development. Beacon Press
2. Daly HE, Farley J (2010) Ecological Economics: Principles and Applications. Island Press
3. Elliott JA (2006) An Introduction to Sustainable Development. Routledge
4. Roosa SA (2010) Sustainable Development Handbook, Second Edition. Fairmont Press
5. Strange T, Bayley A (2008) Sustainable Development: Linking Economy, Society, Environment. OECD

6. Heinrichs H, Martens P, Michelsen G, Wiek A. (2015) Sustainability Science: An Introduction. Springer
7. Filho WL (2017) Handbook of Sustainability Science and Research. Springer
8. Dedeurwaerdere T (2014) Sustainability Science for Strong Sustainability. Elgar Publishing

ME108M. DISASTER RISK MANAGEMENT (MINOR) (2 Credits)

1. **Introduction and overview:** Understanding the concepts and definitions of hazard, disaster, and vulnerability; Risk: types, trends, causes and consequences of disasters; Disaster profile of India.

2. **Institutional framework, policy and guidelines:** Evolution of disaster management in India; Organisation and structure of disaster management in India; National policy on disaster management; National plan on disaster management.

3. **Prevention and mitigation**: Prevention and mitigation; Mainstreaming of disaster risk reduction in developmental strategy; National disaster mitigation fund

4. **Preparedness and response:** Disaster management cycle; Institutional arrangements; Crisis management plan and standard operating procedures; Role of Central and State Governments, National Emergency Operation Centre; National and State Disaster Response Force

5. **Recovery, reconstruction and rehabilitation:** Nature of recovery; Guiding principles for post-recovery, assessment, sustainability in recovery process; Guidance notes on recovery

6. **Capacity development, financial arrangements and international cooperation**: National institutions and disaster management centres in the States; Financing the relief expenditure; Hyogo Framework of Action; Agencies of United Nations involved in disaster management

7. **Application of Science and Technology**: Use of Remote Sensing, GIS and GPS; Early warning and disaster communication; Land use planning; Nature based solutions

8. **Case Studies**: Mega disasters of India and other parts of world.

Suggested Readings

1. MHA (2011) Disaster Management in India, Ministry of Home Affairs (MHA) Govt. of India, New Delhi
2. Srivastava HN, Gupta GD (2006) Management of Natural Disasters in developing countries,Daya Publishers, Delhi
3. Phillips, B (2009) Disaster Recovery. CRC Press
4. Oosterom V et al (2015) Geo-information for Disaster Management, Springer
5. Coppola DP (2015) Introduction to International Disaster Management, 3rd Edition, Elsevier

SECOND SEMESTER

ME201. ENVIRONMENTAL CHEMISTRY & TOXICOLOGY (2 Credits)

1. **Introduction to environmental Chemistry:** Fundamentals of Environmental Chemistry; Scope and future prospects; Tools and techniques in Environmental Chemistry

2. **Chemistry of air:** Physical and chemical properties; Air pollution: sources, sinks of air pollutants and management

3. **Chemistry of water:** Physical and chemical properties; Water pollution: sources, sinks of water pollutants and management

4. **Chemistry of soil:** Physical and chemical properties; Soil pollution: sources, sinks of soil pollutants and management

5. **Toxicity testing and dose response relationship:** Principles and Standards of toxicity testing; Methods in toxicity evaluation at genetic, cellular and molecular level by *in-vivo* and *in-vitro* methods; Dose-response relationship; Detoxification mechanisms in plants, animals and human beings

6. **Toxicity of xenobiotics**: Cellular, molecular and biochemical effects of xenobiotics including persistent organic pollutants (POPs) in living organisms; Remedial measures for reducing POPs toxicity

7. **Toxicology of microbial toxins:** Microbial toxins in environment; Cellular, molecular and biochemical effects of microbial toxins in humans and animals; Food poisoning and control measures

8. **Case studies:** Minamata disease in Japan; Bhopal disaster; Endosulfan pollution in Kerala; Arsenic poisoning in Indo-Gangetic plain and other emerging ecotoxicological issues

Suggested Readings

1. Vanloon GW, Duffy SJ (2010) Environmental Chemistry: a global perspective. Oxford University Press.
2. De AK(2000) Environmental Chemistry, 4thedition. New age International (P) Ltd.
3. Johnson DO, Netterville JT, Wood JC, James M(1973) Chemistry and the Environment.W.B. Saunders Company.
4. Lave LB,Upton AC (1987) Toxic Chemicals, health and the Environment. TheHopkins Press Ltd.
5. Manhan (2000) Environmental Chemistry, 7thedition. CRC Press.
6. Midoand Y, Satake M (2003) Chemicals in the environment. Discovery Publishing House.

ME201P. PRACTICALS BASED ON ME201 (1 Credit)

ME202M. ENVIRONMENTAL ISUES & CHALLENGES (MINOR) (2 Credits)

1. **Man and environment:** Impact of human population on environment; Ethical issues regarding unscientific development and environmental degradation; Impact of global land cover and

land use change; Causes, effects and mitigation strategies for global climate change and stratospheric ozone loss

2. **Environmental pollution:** Causes and effects of air, water, soil, noise, radioactive pollution; Basic pollution abatement practices and technologies

3. **Biotic invasions:** Extent and mechanisms of biological invasions; Ecological and economic impacts; Management strategies

4. **Loss of biodiversity** : Threats and pattern of biodiversity loss; Natural and anthropogenic causes; IUCN threat categories, Red data books; Conservation and restoration of biodiversity

5. **Global water crisis:** Distribution, withdrawal and consumption patterns; Causes and effects of water crisis; Water conservation approaches

6. **Global energy crisis:** Sources of energy supply; Current potential and future prospects of energy sources; Energy crisis; Energy conservation strategies

7. **Challenges of urbanization:** Recent trends of urbanization; Environmental impact of urbanization; Concept of green cities

8. **National policies and action plan on environment:** National Forest Policy; National Water Policy; National Energy Policy; National Action Plan on Climate Change; National Biodiversity Action Plan; Carbon crediting; Green taxes; Clean development Mechanisms

Suggested Readings

1. McConnell R (2008) Environmental issues: An introduction to sustainability. Pearson
2. Wali MK., Evrendilek F, Fennessy M (2009) The environment: science: Issues and solutions. CRC Press
3. Neelin J (2011) Climate change and climate modelling. Cambridge University Press
4. John Marshall R, Plumb A (2008) Atmosphere, ocean and climate dynamics: An introductory text. Elsevier
5. Phillips B,Thomas D, Fothergill A, Blinn-Pike L (2009) Social vulnerability to disasters. CRC Press
6. Hill M (2010) Understanding environmental pollution. Cambridge University Press
7. Morin FJ, Orsini A (2015) Essential Concepts of Global Environmental Governance. Routledge
8. Vig NJ, Kraft ME (2015) Environmental Policy: New Directions for the Twenty-First Century, (9th ed.). CQ Press

ME203. NATURAL RESOURCE MANAGEMENT (2 Credits)

1. **Introduction:** Types of natural resources, their consumption patterns; Human population explosion and resource degradation and conservation; Factors influencing resource availability, distribution and uses; Ecological, social and economic dimension of resource management

2. **Land resources:** Current status of national and global land resources; Land degradation: natural and anthropogenic drivers; Sustainable strategies for land resource management;Role of indigenous and local knowledge (ILK) in land resource management

3. **Water resources:** Current status of national and global water resources; Water pollution; Sustainable strategies for land resource management; Integrated watershed management; Role of indigenous and local knowledge (ILK) in water resource management

4. **Forest resources:** Current status of national and global forest resources; Forest degradation: natural and anthropogenic drivers; Sustainable strategies for forest resource management; Role of indigenous and local knowledge (ILK) in forest resource management

5. **Marine resources**: Current status of global marine resources; Marine pollution: natural and anthropogenic drivers; Sustainable strategies for marine resource management

6. **Minerals resources**: Current status of mineral resources in India; Environmental impact of mineral exploitation; Sustainable strategies for mineral resources management

7. **Energy resources:** Current status of conventional and non-conventional energy sources; Environmental impacts of energy exploitation; Cleaner and alternative sources of energy; Sustainable strategies for energy resources management

8. **Case Studies:** Current case studies related to natural resource management in India

Suggested Readings

1. Singh JS, Gupta SR, Singh SP(2014) Ecology Environmental Science and Conservation, Chand Publishing
2. Pandey BW (2005) Natural Resource Management, Mittal Publications
3. Morin FJ, Orsini A (2015) Essential Concepts of Global Environmental Governance. Routledge, ISBN 978-0-41582-247-3
4. Anderson DA (2013) Environmental Economics and Natural Resource Management, Routledge
5. Knight RL, Bates SF (1995) A New Century for Natural Resources Management, Island Press
6. Chiras DD, Reganold JP (2013) Natural Resource Conservation: Pearson New International Edition: Cases and Moral Reasoning, Pearson Education Limited

ME203P. PRACTICALS BASED ON ME203 (1 Credit)

ME204. REMOTE SENSING & GIS (2 Credits)

1. **Basics of remote sensing:** Background and history of remote sensing; Fundamentals of remote sensing: electromagnetic radiation, energy matter interaction; Platforms and sensors; Characteristics of images; Optical and microwave satellites

2. **Digital image processing:** Digital image data formats; Image rectification and restoration techniques: geometric correction, radiometric correction and noise suppression, image histograms, density slicing; Image enhancement techniques: contrast manipulation, spatial filtering and edge enhancement, atmospheric correction of satellite images

3. **Geographic Information Systems:** Fundamentals of GIS, vector, raster and attribute data models, vector and raster data structure; Spatial data input and editing; Visualization and query of spatial data;Spatial data transformations, spatial analysis

4. **Multi-image manipulations:** Spectral rationing, vegetation indices; Principal components analysis; Multi and hyper-spectral image classification; Supervised and unsupervised algorithms; Object based classification

5. **Microwave remote sensing:** Introduction to microwave remote sensing; Radar and radiometer, radiative transfer; Microwave missions and products definitions

6. **Hyperspectral remote sensing:** Introduction to hyperspectral remote sensing, hyperspectral radiometer; Hyperspectral missions and products definitions

7. **Global navigational satellite system:** Basics of GNSS; Concept of global positioning system (GPS), working of GPS, types of GPS; Differential GPS; Future GPS and applications of GPS

8. **Case studies:** RS and GIS applications in air quality modelling, early warning, urban planning, biodiversity and forest mapping, snow cover simulation, ocean salinity, disaster management.

Suggested Readings

1. Islam T, Alexander YH, Wang KJ (2018) Remote Sensing of Aerosols, Clouds, and Precipitation. Elsevier
2. Burrows JP, Platt U, Borell P (2014) The Remote Sensing of Tropospheric Composition from Space. Springer
3. Kokhanovsky AK, Leeuw GD (2013) Satellite aerosol remote sensing over land. Springer
4. Joseph G (2009). Fundamentals of Remote Sensing. University Press
5. Huisman O, de RA (ed.) Principles of Geographic Information Systems, Fourth edition. ITC Educational Textbook Series. ITC, Enschede, The Netherlands

ME204P. PRACTICALS BASED ON ME204 (1 Credit)

ANY ONE PAPER AS PER THE CHOICE BASED CREDIT SYSTEM (2 Credits)

ME210.MICROBIOLOGY (2 Credits)

1. **Diversity of microbial world:** Classification, characteristics, occurrence, distribution and diversity of microorganisms; Ultrastructure of archaea, eubacteria, unicellular eukaryotes (yeast) and viruses

2. **Methods in microbiology:** Methods of studying microbial diversity; Pure culture techniques, isolation, cultivation, maintenance and preservation of pure cultures and sterilization techniques. Microbial growth: Batch, fed-batch, continuous kinetics, synchronous growth, yield constants; methods of growth estimation.

3. **Molecular tools in microbiology:** Denaturing Gradient Gel Electrophoresis (DGGE), Temperature Gradient Gel Electrophoresis (TGGE); Amplified rDNA Restriction Analysis (ARDRA) and Terminal Restriction Fragment Length Polymorphism (T-RFLP) in assessing microbial diversity; 16S rDNA sequencing and Ribosomal Database Project (RDP)

4. **Microbes in extreme environments:** Habitat, biodiversity, adaptive strategies and biotechnological potential of thermophiles and hyperthermophiles; Psychrophiles and psychrotrophs; Halophiles, acidophiles and alkalophiles; Methanogens

5. **Microbes and ecosystem:** Microbial communities and ecosystems; Microbial community dynamics; Structure of microbial communities: Asexual reproduction; Transformation, transduction and conjugation

6. **Biogeochemical cycles and microbes:** Role of microorganisms in carbon, nitrogen, sulfur and phosphorous cycling; Biological nitrogen fixation, Role of microbes of cycle of other elements

7. **Microbes and environment:** Plant-microbe interactions; Mycorrhizae; Role of microorganisms in natural system and artificial system; Influence of microbes on the Earth's environment

8. **Microbial applications:** Plant growth promoting rhizobacteria; Role of microorganisms in wastewater treatment, bioremediation and food security

Suggested Readings

1. Pelczar MJ Jr, Chan ECS, Krieg NR (2001) Microbiology, 5th edition, McGraw Hill education India Private Ltd
2. Willey J, Sherwood L, Woolverton C (2010) Prescott's Microbiology, 8th edition, McGraw Hill Education
3. Maloy SR, Cronan JE Jr, Freifelder D (2006) Microbial Genetics, Jones Bartlett Publishers, Sudbury, Massachusetts
4. Madigan MT, Martinko, JM (2006) Biology of Microorganisms, 11th Edition, Pearson Prentice Hall, USA
5. Swanson TA, Kim S, Flomin OE (2008) Microbiology, Lippincott Williams & Wilkins
6. Pommerville JC, (2017) Fundamentals of Microbiology, Jones & Bartlett Learning
7. Madsen EL (2015) Environmental Microbiology: From Genomes to Biogeochemistry, John Wiley & Sons

ME210P.PRACTICALS BASED ON ME210 (1 Credit)

ME206M. ENVIRONMENTAL IMPACT ASSESSMENT (MINOR) (2 Credits)

1. **Origin and Scope of EIA:** Origin of Environmental Impact Assessment (EIA); Principles and scope; Indian policies regarding EIA; Developmental projects requiring EIA; ISO 14000

2. **Steps of EIA:** Screening; Scoping; Impact prediction; Consideration and comparison of alternatives; Stakeholder involvement; Compensatory actions and mitigation measures; Preparation of EIA report; Review and decision making

3. **Methods for EIA:** Methods for organizing and presenting information: Ad Hoc Method; Checklists; Scales and Weights, Matrices; Networks and overlay approaches; Simulation Modelling, Spatially Based Methods; Rapid Assessment, Risk and Uncertainty in EIA

4. **Approaches to impact prediction:** Physical, experimental, computer and mathematical Models; Predicting quantitative & qualitative environmental changes in components of environment

5. **EIA for developmental programmes:** EIA for various Industries; Urban development; Energy projects; EIA for resources management

6. **Strategic environmental assessment:** Aims, principles and scope of Strategic Environmental Assessment (SEA); Importance and limitations; Procedures; Comparison of SEA and EIA

7. **Socioeconomic impact analysis:** Aims, Principles and scope of Socioeconomic Impact Analysis (SIA), Basic steps in SIA, Analysis of public services and facilities impacts; Fiscal impact analysis

8. **Case Studies:** Current case studies related to environmental impact assessment such as Narmada Project, Valley of Flowers, Coal Mining Projects

Suggested Readings

1. Abaza H, Bisset R, Sadler B (2004) Environmental Impact Assessment and Strategic Environmental Assessment: Towards an Integrated Approach. UNEP, Geneva
2. Anjaneyulu Y, Manickam V (2011) Environmental Impact Assessment Methodologies. CRC Press
3. Eccleston CH (2017) Environmental Impact Assessment: A Guide to Best Professional Practices. CRC Press
4. Lawrence DP (2003) Environmental Impact Assessment: Practical Solutions to Recurrent problems. John Wiley & Sons, Inc., New Jersey.
5. Morgan RK Environmental Impact Assessment: A Methodological Approach. Springer US.
6. Mareddy AR, Shah A, Davergave N (2017) Environmental Impact Assessment: Theory and Practice. Butterworth-Heinemann Pub
7. Wood C (2014) Environmental Impact Assessment: A Comparative Review. Routledge
8. Glasson J, Therivel R, Chadwick A (2013) Introduction to Environmental Impact Assessment. Routledge,
9. Hanna KS (2015) Environmental Impact Assessment: Practice and Participation. Oxford University Press

ME207: SCIENCE COMMUNICATION (THEMATIC REVIEW & PRESENTATION) (1 Credit)

ME208: STUDY TOUR/EXPERIENTIAL LEARNING (2 credits)

THIRD SEMESTER

ME301. STATISTICAL METHODS (2 Credits)

1. **Data and its properties:** Types of data; Scales of measurement; Data distribution; Tabular and Graphical presentation of data

2. **Descriptive statistics:** Populations and Samples; The Frequency distribution; Measures of central tendency, dispersion and shape; The normal distribution and Central Limit Theorem; Confidence intervals for population mean; The standard score

3. **Student's t test:** The nature of t distributions; One-sample t-test; Two-sample t-test; Repeated measures t-test; Unequal variance t-test

4. **Analysis of variance:** Assumptions for use of the ANOVA; The nature of F distribution; The completely randomized design; The randomized complete block design; The repeated measures design; Factorial experiments; Multiple comparisons of means

5. **Chi-Square tests:** The nature of chi-square distributions; Goodness-of-fit tests; Contingency table analysis; Relative risks and odds ratios

6. **Correlation and regression:** Scatterplot; The Pearson product-moment correlation coefficient; The regression line; The accuracy of prediction; Assumptions underlying regression and correlation; The Coefficient of Determination; Multiple Regression; Multiple Correlation and Partial Correlation

7. **Nonparametric statistics:** Distribution-free Tests; The Sign Test; The Wilcoxon Rank Sum Test for Independent Samples; The Wilcoxon Signed Rank Test for the Paired Difference Experiment; The Kruskal–Wallis Test for a Completely Randomized Test; The Friedman Test for a Randomized Block Design; Spearman Rank Correlation Coefficient

8. **Case studies:** Statistical analysis of Varanasi Census and Climate data using Excel, SPSS and R

Suggested Readings

1. Sokal RR, Rohlf JF (2009) Introduction to Biostatistics, 2nd Ed. Dover Publications, Inc., Mineola, New York.
2. Zar, JH (2009) Biostatistical Analysis, 5th Ed. Prentice Hall.
3. Reimann C, Filzmoser P et al. (2009) Statistical Data Analysis Explained: Applied Environmental Statistics With R. Wiley Online Library.
4. Weaver KF, Morales VC, Dunn SL, Godde K, Weaver PF (2018) An Introduction to Statistical Analysis in Research-With Applications in the Biological and Life Sciences. John Wiley & Sons, Inc.

ME301P. PRACTICALS BASED ON ME301 (1 Credit)

ME332.MOLECULAR BIOLOGY & GENETIC ENGINEERING (2 Credits)

1. **Nucleic acid structure:** Prokaryotic and eukaryotic genome; Structure of DNA; Chromosome organization; Heterochromatin and Euchromatin; Repetitive and unique sequences; Satellite DNA; DNA melting and buoyant density; DNA reassociation kinetics (Cot curve analysis); Nucleosome phasing; DNA methylation and Imprinting

2. **DNA replication, repair and recombination:** Replication in prokaryotes and eukaryotes; Enzymes and accessory proteins; Fidelity; Replication of single stranded circular DNA; Gene stability and DNA repair; Recombination; Gene targeting; Gene disruption

3. **Expression of genetic information:**Operon concept; Transcription in prokaryotes and eukaryotes; DNA-protein interaction; Transcription factors, post transcriptional modification and protein transport, Genetic code; Mechanism of translation and its control, post translational modifications

4. **Gene mutation:** Nonsense, missense and point mutations; Intragenic and Intergenic suppression; Frameshift mutations; Physical, chemical and biological mutagens; Transposition and its mechanism in prokaryotes and eukaryotes; Role of transposons

5. **Recombinant DNA technology:** Enzymes of recombinant DNA technology; Linkers; Adaptors; DNA Labeling: Nick translation, Random priming, Probes, Hybridization techniques: Northern, Southern and Colony hybridization, Chromatin Immunoprecipitation; DNA-Protein Interactions-Electromobility shift assay; DNaseI footprinting

6. **Vector Biology:** Plasmids; Bacteriophages; Vectors (Plant, Animal Virus, Yeast based vectors, M13 vectors; pUC19, Lambda vectors, YACs etc.); Insertion of Foreign DNA into Host Cells; Construction and screening of genomic and cDNA libraries; Cloning; Yeast two hybrid system; Transformation; Transfection; Gene knockouts

7. **Polymerase Chain Reaction:** Types of PCR; Primer design; cloning of PCR products; Proof reading enzymes; Application of PCR in gene recombination; Site directed mutagenesis; Molecular diagnostics; Viral and bacterial detection; Mutation detection

8. **Case Studies:** Application of gene silencing, Transgenics; Cisgenics

Suggested Readings

1. Govil CM, Aggarwal A, Sharma J (2017) Plant Biotechnology and Genetic engineering, PHI Learning Pvt Ltd
2. Karp G (2013) Cell and Molecular Biology, 7th edition, John Wiley & Sons
3. Glick BJ, Pasternack JJ, Patten CL (2010) Molecular Biotechnology: Principles and Applications of Recombinant DNA, 4th edition, American Society for Microbiology
4. Brown, T.A. (2010) Gene cloning and DNA analysis: An Introduction, 6th edition, Wiley-Blackwell
5. Lewin B (2007) Genes IX, Jones and Bartlett Learning
6. Brown, TA (2006) Genomes 3, Garland Science
7. Sambrook J, Russell DW (2001) Molecular Cloning – A Laboratory Manual, Vols. I – III. Cold Spring Harbor Laboratory,

ME332P. PRACTICALS BASED ON ME332 (1 Credit)

ME333. ADVANCED BIOTECHNOLOGICAL TOOLS &BIOINFORMATICS (2 Credits)

1. **Basic Techniques:** Buffers; Methods of cell disintegration; Protein extraction; Enzyme assays and controls; Dialysis, Ultrafiltration and other membrane techniques

2. **Centrifugation and Spectroscopy Techniques:** Basic principles of centrifugation; Microcentrifuge, High speed & Ultracentrifuges; Preparative centrifugation; Differential & density gradient centrifugation; Analytical centrifugation; Principles of Spectroscopy; UV,

Visible and Raman Spectroscopy; Circular Dichroism; Fluorescence; MS, ESR and Plasma Emission spectroscopy

3. **Chromatography and Electrophoretic techniques:** TLC and Paper chromatography; Gel permeation, Ion exchange, Hydrophobic, Reverse-phase and Affinity chromatography; HPLC; Polyacrylamide and Agarose gel electrophoresis; Capillary electrophoresis; 2D Electrophoresis; Disc gel electrophoresis; Gradient electrophoresis; Pulsed field gel electrophoresis

4. **Radioactivity:** Radioactive & stable isotopes; Radioactive decay; Units and Measurement of radioactivity; Geiger-Muller counter; Solid & Liquid scintillation counters; Radiation dosimetry; Cerenkov radiation; Autoradiography; Measurement of stable isotopes; Radiotracer techniques; Radioimmunoassay

5. **Advanced Techniques:** Protein crystallization; Theory and methods; API-electrospray and MALDI-TOF; Mass spectrometry; Enzyme and cell immobilization techniques; DNA & Peptide Synthesis

6. **Basics of Bioinformatics:** Introduction to bioinformatics, searching database, alignment of gene sequences – local and global, phylogeny analysis and construction of phylogeny maps.

7. **Analyzing DNA and Proteins: Bioinformatics:** Gene prediction and locating genes, location of transcription start point and end point, primer designing, generation of restriction maps. protein classification, homology modelling, threading, Ab-initio prediction of protein structure, tools for structure prediction, validation and visualization

8. **Imaging and Microscopy techniques:** Microscopy principles, light and dark field microscopy, fluorescence and confocal microscopy, Scanning electron microcopy, transmission electron microscopy, Atomic force microscopy, X-ray and laser based imaging tools, Image analysis software

Suggested Readings

1. Wilson K, Walker J (2010), Principles and Techniques of Practical Biochemistry, 7th Edition, Cambridge University Press
2. Lesk A M (2013) Introduction to Bioinformatics, Oxford University Press
3. Xiong J (2006) Essential Bioinformatics, Cambridge University Press
4. Higgins D, Taylor W (2000) Bioinformatics: Sequence, Structure and Databanks – A practical approach, Oxford University Press
5. Dubey RC (2014) Advanced Biotechnology, S Chand Publishing
6. Holme D, Peck H (1998) Analytical Biochemistry, 3rd Edition, Longman
7. Scopes R (1994) Protein Purification - Principles & Practices, 3rd Edition, Springer Verlag

ME333P. PRACTICALS BASED ON ME333 (1 Credit)

ME334.ANIMAL BIOTECHNOLOGY (2 Credits)

1. **Animal cell and tissue culture:** Structure of animal cell; History of animal cell culture; Cell culture media and reagents; Culture of mammalian cells, tissues and organs

2. **Animal cell cultures and cell line:** Primary culture, secondary culture, continuous cell lines, suspension cultures; Somatic cell cloning and hybridization; Transfection and transformation

of animal cells; Commercial scale production of animal cells; various established and available animal cell lines

3. **Animal cell culture technology:** Application of animal cell culture for *in vitro* testing of drugs; Testing of toxicity of environmental pollutants in animal cell culture; Hybridoma technology; Phage display technology for production of antibodies

4. **Vaccines:** Introduction to the concept of vaccines; History of development of vaccines; Conventional methods of animal vaccine production; Recombinant approaches to vaccine production; Application of cell culture technology in production of human and animal viral vaccines and pharmaceutical proteins

5. **Immunotechnology:** Antigen-antibody based diagnostic assays including radio-immunoassays and enzyme immunoassays; Immunoblotting; Nucleic acid based diagnostic methods; Commercial scale production of diagnostic antigens and antisera; animal disease diagnostic kits

6. **Germ cells and cryopreservation:** Structure of germ cells; Cryopreservation of germ cells of livestock; *in situ* and *ex situ* preservation of germplasm; Artificial insemination; Super ovulation; *in vitro* fertilization; Culture of embryos; cryopreservation of embryos; Embryo transfer; Transgenic manipulation of animal embryos

7. **Animal cloning:** Basic concept of animal cloning; Cloning from embryonic cells and adult cells; Cloning of different animals; Cloning for conservation of endangered species; ethical, social and moral issues related to cloning; *in utero* testing of foetus for genetic defects; gene knock out technology and animal models for human genetic disorders

8. **Case studies:** Transgenic animal production and application in expression of therapeutic proteins; Immunological and nucleic acid based methods for identification of animal species; Identification of wild animal species applying DNA based methods using different parts like bones, hair, blood, skin and others with case studies

Suggested Readings

1. Freshney RI (2010) Culture of Animal cell, 6th edition. Wiley-Blackwell.
2. Masters JRW (ed.) (200) Animal cell culture- Practical approach 3rd edition, Oxford University Press.
3. Sasidhara R (2009) Animal Biotechnology. MJP Publishers.
4. Verma A, Singh A (2013) Animal Biotechnology: Models in Discovery and Translation, Elsevier.
5. Kumaresan V (2014) Animal Biotechnology, SaraS publishers.
6. Ranga MM (2007) Animal Biotechnology, Agrobios publishers.
7. Ramadass P(2008) Animal Biotechnology: Recent Concepts and Developments, MJP publishers.

ME334P. PRACTICALS BASED ON ME334 (1 Credit)

ME335. BIORESOURCE TECHNOLOGY & ENVIRONMENTAL ENGINEERING (2 Credits)

1. **Pollutants in water and wastewater:** Characteristics; Standards for performance; Significance of physico-chemical treatment; Physical and chemical treatment principles

2. **Water treatment plant:** General layout of Water Treatment Plant – Aerators- types and design; Flash Mixer –Design; Clariflocculator- parameters for design; Filtration - Rapid sand

filter and Pressure filter and calculation of chlorine dosage; chlorine demand and residual chlorine

3. **Biological treatment of wastes:** Biological treatment systems-Significance, aerobic and anaerobic treatment kinetics of biological growth; Biodegradability assessment; Design of aerobic and anaerobic treatment systems

4. **Waste treatment processes :** Sludge Processing and Disposal Methods – Design of Anaerobic Digester and Sludge Drying Bed; Reverse Osmosis; Ion Exchange; Incinerators and Multiple Evaporators; Land filling – Composting, Vermicomposting – Bioprocess

5. **UNIT – V :** Design of Pressure Pipes – Darcy – Weisbach Formula, Manning's Formula, Hazen – William's Formula – limiting velocities, Minimum and Maximum Test Pressure and Working Pressure in pipes – selection of pipe material – Pump types, Characteristic Curves – selection and determination of capacity; Sanitary appliances

6. **Air pollutants:** Contaminants-aerosol, gases and vapour, Air quality, Control of air pollutants and particulates: Filters, gravitational, centrifugal – multiple type cyclones, collection efficiency, pressure drop, wet collectors, design of ESP

7. **Control of gaseous pollutants**:Absorption; Adsorption; principles, description of equipment's and performance; Condensation; Incineration

8. **Control measures for industrial applications:** Control methods – Processes based control mechanisms – mineral products – asphaltic concrete, cement plants and glass manufacturing plants; Thermal power plants, Petroleum refining and storage plants, Fertilizers, Pharmaceuticals and wood processing industry

Suggested Readings

1. Metcalf and Eddy (2003) Wastewater Engineering, Treatment and Reuse. Tata McGraw Hill Publishing Company Ltd.
2. Lee CC, Lin SD (1999) Handbook of Environmental Engineering Calculations. McGraw Hill.
3. Hendricks D (2006) Water Treatment Unit Processes – Physical and Chemical. CRC Press.
4. de Nevers N (1995) Air Pollution Control Engineering. McGraw Hill.
5. Masters GM (2004) Introduction to Environmental Engineering and Science. Prentice-Hall of India Pvt. Ltd., New Delhi.
6. Spellman FR(2003) Handbook of Water and Wastewater Treatment Plant Operations. Lewis Publishers.
7. Peavy HS (2003) Environmental Engineering. Tata McGraw Hill Publishing Company Ltd.

ME335P. PRACTICALS BASED ON ME335 (1 Credit)

ME336. BIOSAFETY, IPR &ENTERPRENEURSHIP (2 Credits)

1. **Intellectual property and its types:** Historical background; Patents, trademarks, copyright & related rights; Industrial Design; Traditional Knowledge; Geographical Indications; Protection of New GMOs; International framework for the protection of Intellectual Property; Intellectual Property as a factor in research and development

2. **Patents:** Types of patent applications; Ordinary, PCT; Specifications, provisional and complete; Forms and fees invention in context of "prior art"; Patent databases; Searching international and national databases

3. **Patenting procedures:** National & PCT filing procedure; Time frame and cost; Status of the patent applications filed; Precautions; Patent licensing and agreement; Patent infringement-meaning, scope, litigation, case studies

4. **Biosafety and regulations**: Definition; Historical background; Biotechnology and bio-safety concerns; Primary Containment for Biohazards; Biosafety Levels; Biosafety guidelines - Government of India; GMOs & LMOs; Roles of Institutional Biosafety Committee, RCGM, GEAC etc. for GMO applications in food and agriculture

5. **Environmental concerns and bioethics:** GMOs; Risk Assessment; Analysis and management; National Regulations and International Agreements including Cartagena Protocol; Bioethics, different paradigms of bioethics- national and international; Ethical issues against molecular technologies

6. **Entrepreneurship:** Definition and Meaning; Characteristics; Functions; Types; Strategies; Entrepreneurship and Innovation; The Innovation Concept and Importance; The Innovation Process; Product life cycle, new product development process, mortality curve; Creativity and innovation in product modification/ development

7. **Biotechnology entrepreneurship**: Structure of a Biotechnology Company; New Product Development; Market Research; Sales and Marketing Principles; Role of Government in Biotechnology industry; Legal Issues for the Entrepreneur

8. **Case Studies:** Start-up of Biotechnology Company

Suggested Readings

1. Paul M (2009) Intellectual Property Laws, Allahabad Law Agency
2. Intellectual Property Law (Containing Acts, Rules and Regulations) (2015) Universal Law Publication Company
3. Oliver R (2000) The coming Biotech age: The business of Biomaterials. McGraw Hill Publications
4. Karthikeyan S, Arthur R (2009) Biobusiness, MJP Publications
5. Bulger RE (1993) The ethical dimensions of the Biological Sciences, Cambridge University Press
6. Shahi G (2004) BioBusiness in Asia: How countries Can Capitalize on the Life Science Revolution, Pearson Prentice Hall
7. Robbins C (2001) The business of Biotechnology. UK, Harper Collins

ME336P. PRACTICALS BASED ON ME336 (1 Credit)

ME337. FOOD TECHNOLOGY (2 Credits)

1. **Non-conversion operations:** Food raw materials, physical, functional and other properties; Cleaning of raw materials - methods and contamination; Sorting, grading of food materials

2. **Food conversion operations:** Size reduction and screening of solids- equipment, modes of operation; Disintegration of materials, mixing and emulsification, filtration, centrifugation, heat processing

3. **Chemistry of Food:** Food groups and importance of food chemistry; Water in foods; Sources, properties and function of carbohydrate, proteins, fat, minerals, vitamins and antioxidants; Hydrogenation and rancidity; Saponification number, iodine value, Reichert-Meissl number

4. **Food Microbiology:** Important microorganisms and the factors affecting their growth and survival in foods; food spoilage; Microbial agents of food borne illnesses; Microbial cultures for food fermentation; Pasteurization and sterilization

5. **Food preservation and Non-thermal Processing Operations of Foods:** Objectives and techniques of food preservation; Low temperature preservation; Ionization radiation; chemical preservative, biopreservative including antibiotics; thermal technologies; Nutritional and consumer considerations

6. **Labelling and Packaging of Foods:** Structures of packages, degradability, reusability and regulations; Types of packages and labelling guidelines of foods; Canning, spoilage in canned foods

7. **Management of Food Wastes:** Characteristics of food waste and its management; Current treatment options – overview; Feasibility of reuse and conversion processes for value added products

8. **Case Study:** Case studies in food production and technology

Suggested Readings

1. Singh RP, Heldman DR (2013) Introduction to Food Engineering, 5th edition, Academic Press
2. Berk Z (2013) Food Process Engineering and Technology, 2nd edition, Academic Press
3. Cambell-Platt G (2009) Food Science and Technology, wiley-Blackwell
4. Fellows PJ (2005) Food Processing Technology: Principles and Practice, 2nd edition, Woodhead Publishers Ltd
5. Mariott NG (2005) Principles of Food sanitation, 5th edition, Kindle Publication
6. Whitehurst RJ, Oort MV (2009) Enzymes in Food Technology, John Wiley & Sons

ME337P. PRACTICALS BASED ON ME337 (1 Credit)

ME338. GENOMICS AND PROTEOMICS (2 Credits)

1. **Genome structure:** Organization of prokaryotic and eukaryotic genomes; Organellar DNA-mitochondrial and Chloroplast; Strategies for genome sequencing and sequence assembly

2. **Sequencing genomes:** Genome sequencing projects; Accessing and retrieving genome project information from web; Comparative genomics; Tools for genome analysis

3. **Genome analysis:** Gene inactivation and gene over expression; Approaches to analyze global gene expression - Serial Analysis of Gene Expression (SAGE), Expressed Sequence Tags (ESTs), Massively Parallel Signature Sequencing (MPSS), microarray and its applications, gene tagging

4. **Genomes to proteomes:** Protein extraction methods and sample preparation for proteomic analyses; Sample handling and storage; Protein detection and quantification methods

5. **Proteomic techniques for analysis**: 2-D gel electrophoresis; Mass Spectrometry; N-terminal determination methods; Protein modification; Protein microarrays; Data Analysis algorithms

6. **Applications of proteomics:** Mining Proteomes; Protein expression profiling; Identifying protein-protein interactions and protein complexes

7. **Environmental genomics:** Metagenomics - Prospecting for novel genes from metagenomes and their biotechnological applications

8. **Data mining** Data analysis with bioinformatics tools – Local and global sequence alignment; Needleman Wunsch and Smith-Waterman algorithm; Multiple sequence alignment; Phylogenetic tree construction; Secondary structure prediction; three dimensional structure; Homology modelling; Active site prediction; Docking; Pre-processing of Microarray data; Clustering; Feature selection; Network analysis; Time-series analyses

Suggested Readings

1. Brown, TA, (2006) Genomes, 3rd Edition. Garland Science
2. Campbell, AM, Heyer, LJ (2007) Discovering Genomics, Proteomics and Bioinformatics, 2nd Edition, Benjamin Cummings
3. Twyman, RM (2013) Principles of Proteomics. Garland Science
4. Pennington SR, Dunn MJ (Eds.) (2002) Proteomics: From Protein Sequence to Function. BIOS Scientific Publishers
5. Sambrook J, Russell, DW (2001) Molecular Cloning – A Laboratory Manual, Vols. I – III. Cold Spring Harbor Laboratory, Press
6. Gromiha MM (2011) Protein Bioinformatics: From Sequence to Function, Academic Press
7. Lesk A (2012) Introduction to Genomics, OUP Oxford

ME338P. PRACTICALS BASED ON ME338 (1 Credit)

ME339. INDUSTRIAL BIOTECHNOLOGY (2 Credits)

1. **Bioprocess development:** Principles of fermentation; Bioprocess optimisation; Fermentation media; Bioreactor design and its modifications; Large-scale plant and animal cell culture

2. **Sterilisation and scale-up:** Sterilisation of air and fermentation media; Aeration and agitation in bioprocesses; Scale-up of fermentation processes; Instrumentation and process control in bioprocesses

3. **Downstream processing:** Production, optimization and downstream processing of the metabolite

4. **Production of industrial products:** Amino acid biosynthesis and regulation; Industrial production of glutamate; Fermentation kinetics; Production of penicillin, streptomycin, citric acid, ethanol etc.; Recombinant DNA products using bioreactor

5. **Enzyme technology:** Industrial enzyme technology – production, recovery and formulation of bacterial and fungal enzymes like amylases, proteases, penicillin acylase and glucose isomerase

6. **Microbes for Industry:** Screening and strain improvement of microorganisms for metabolite production; Immobilised enzymes and cell-based bio-transformations of steroids; Microbial production of health care products; Biosensors

7. **Microbial engineering:** Strategies for development of industrial microbial strains with scale up production capacities; Metabolic pathway engineering of microbes for production of novel product for industry

8. **Case study:** Biomass production involving single cell protein; Production of eco-friendly agricultural chemicals, biopesticides, bio-herbicides, bio-fertilizers and bio-fuels

Suggested Readings

1. Stanbury PF, Whitaker A, Hall, SJ (2008) Principles of Fermentation Technology, Elsevier.
2. Shuler M, Kargi F (2002) Bioprocess Engineering. Prentice Hall (I) Ltd
3. Mansi EMT, Bryce CFA, Dmain AL, Alliman AR (2009) Fermentation Microbiology and Biotechnology. Taylor and Francis
4. Thangadurai D, Sangeetha J (2016) Industrial Biotechnology: Sustainable Production and Bioresource Utilization, CRC Press
5. Reddy SM (2012) Basic Industrial Biotechnology, New Age International Publisher
6. Shastri V (2006) Industrial Biotechnology, Gyan Publishing House

ME339P. PRACTICALS BASED ON ME339 (1 Credit)

ME340. NANOBIOTECHNOLOGY (2 Credits)

1. **Introduction of nanomaterials:** The nanoscale dimension and paradigm; Historical evolution and current practice; Types of nanomaterials and their classifications; Biomaterials – Structures and characteristics

2. **Fundamentals of nanomaterials:** Overview of synthetic methods; Surfactants, polymers, emulsions; Micelles/reverse micelles and colloids; Biological Methods; Growth and stabilization, self-assembly

3. **Properties and characterization of nanomaterials:** Optical, X-ray diffraction, Imaging and size, Surface and composition, vibrational, magnetic, electrical and electrochemical

4. **Applications of nanomaterials in biosystems:** Proteins, lipids, RNA and DNA, protein targeting; Small Molecule/Nanomaterial-protein Interactions; Nanomaterial-cell interactions; Polyvalency

5. **Nanomaterials in diagnostics/drug delivery and therapeutics:** MRI; Imaging Surface Modified Nanoparticles; MEMS/NEMS based on nanomaterials peptide/DNA coupled nanoparticles; Lipid nanoparticles; Inorganic nanoparticles; Metal/metal oxide nanoparticles; Nanomedicine today

6. **Toxicity of nanomaterials:** Evaluation of cyto-toxicity, geno-toxicity; In vivo tests/assays

7. **Bionanotechnology:** Overview- what can engineers learn from biology; Bio-nanomachines in actions a molecular recognition- how molecular recognition underlies cellular communication, material transfer into and within cells, and biotransformation; Information: How information is stored in the cell and how it is read

8. **Structural and functional Principles of bionanotechnology:** Natural bionano-machinery; Hierarchical strategy, raw materials; Protein folding, self-assembly and self-organization, molecular recognition and flexibility; Information driven nano assembly; Biomolecular motors; Biomolecular sensing, self replication and machine- phase bionanotechnology

Suggested Readings

1. Decher G, Schlenoff JB (eds.) (2003) Multilayer Thin Films. Wiley- VCH
2. Goodsell, DS (2004) Bionanotechnology: Lessons from Nature, 1st Edition, Wiley-Liss
3. Malsch NH (2005) Biomedical Nanotechnology, 1st Edition. CRC Press
4. Salati G (eds.) (2016) Principles and Practices of Nanobiotechnology, Syrawood Publishing House
5. Phoenix, DA, Ahmed, W (eds.) (2014) Nanobiotechnology, One Central Press
6. Niemeyer CM, Mirkin CA (2012) Nanobiotechnology, Volume I, Wiley-VCH
7. Niemeyer CM, Mirkin CA (2012) Nanobiotechnology, Volume II, Wiley-VCH

ME340P. PRACTICALS BASED ON ME340 (1 Credit)

ME341.PLANT BIOTECHNOLOGY (2 Credits)

1. **Plant cell and tissue culture:** Structure of plant cell; History of plant tissue culture; Tissue culture media (composition and preparation); Initiation and maintenance of callus and suspension culture; Single cell clones

2. **Organ culture and its applications:** Organogenesis; Somatic embryogenesis; Shoot-tip culture; Production of virus-free plants; Pathogen indexing; Embryo culture and Embryo rescue; Anther, pollen and ovary culture for production of haploid plants and homozygous lines

3. **Protoplast culture and its applications:** Protoplast isolation, culture and fusion; Selection of hybrid cells and regeneration; Symmetric and asymmetric hybrids; Cybrids; Somaclonal Variation; *in-vitro* mutation methods; Biotransformation; and DNA banking for germplasm conservation

4. **Plant vectors:** Methods for genetic transformation and transgenic plants production through *Agrobacterium tumefaciens* and *Agrobacterium rhizogenes*; Features of Ti and Ri plasmids; Role of virulence genes; The basis of tumour formation, hairy root generation, Use of Ti and Ri as vectors; Binary vectors

5. **Gene transfer methods in plants:** PEG-mediated, microinjection, particle bombardment, electroporation; Molecular markers and their importance in plant breeding, Marker Assisted Selection (MAS); Chloroplast transformation-advantages, vectors, success with tobacco and potato

6. **Plant transformation:** Application of plant transformation for productivity and performance; herbicide resistance; insect resistance; resistance against pathogens (bacteria, viruses and fungi); Nematode resistance; Abiotic stress tolerance; Terminator gene technology

7. **Secondary metabolites:** Production of secondary metabolites; Sources of plant secondary metabolites; Criteria for cell selection; Factors affecting the culture of cells; Different bioreactors and their use in secondary metabolite production

8. **Case study:** Metabolic engineering and industrial products; Control mechanisms and manipulation of pheylpropanoid pathway, alkaloids, industrial enzymes, biodegradable plastics, polyhydroxybutyrate; Therapeutic proteins, antibodies, edible vaccines; Purification strategies taking case studies

Suggested Readings

1. Hammond J, Macgarvey P, Yusibov V (2012) Plant biotechnology: New Products and Applications. Springer-Verlag
2. Henry RJ, (ed.) (1997) Practical application of plant molecular biology. Chapman & Hall
3. Razdan, MK (2003) Introduction to plant tissue culture, 2nd edition. Science Publishers.
4. Mantell, SH, Matthews JA, McKee RA (1985) Principles of plant biotechnology: An introduction to genetic engineering in plants. Blackwell Science Inc
5. Chawla HS (2017) Introduction to Plant Biotechnology 3rd edition, CRC Press
6. Ricroch A, Chopra S, Fleischer SJ (2014) Plant Biotechnology: Experience and Future Prospects, Springer
7. Altman A, Hasegawa P (2011) Plant Biotechnology and Agriculture: Prospects for the 21st Century, Academic Press

ME341P. PRACTICALS BASED ON ME341 (1 Credit)

ME342. IMMUNOLOGY (2 Credits)

1. **Fundamental concepts of Immunology:** Components of innate and acquired immunity; Phagocytosis; Complement and Inflammatory responses

2. **Anatomy of immune system:** Cells and organs of immune system; hematopoiesis; Antigens; Haptens, adjuvants immunoglobulins and monoclonal antibodies; Antigen antibody interaction

3. **Immunoglobulins structure and function:** Immunoglobulins-basic structure, classes and subclasses of immunoglobulins, antigenic determinants;Multigene organization of immunoglobulin genes; Immunoglobulin superfamily

4. **Immunoglobulins function:** Immunoglobulin and TCR genes and generation of diversity; VDJ rearrangements; Immunoglobulin gene expression and its regulation; B and T cell interaction; B-cell receptor; B cell maturation, activation and differentiation; T-cell maturation, activation and differentiation and T-cell receptors

5. **Major histocompatibility complex:** Structure and function; Immunological memory; Complement system; Action of cytotoxic T lymphocytes

6. **Advanced immunological techniques:** RIA, ELISA, western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; Surface plasmon resonance, biosensor assays for assessing ligand –receptor interaction; Cell cytotoxicity assays, apoptosis

7. **Vaccinology:** Active and passive immunization; Live, killed, attenuated, sub unit vaccines, recombinant DNA and protein based vaccines, plant-based vaccines, Immunity to Infection

8. **Immunology in health and disease:** Immunity to Infection; Hypersensitivity; Immunological disorders, graft transplantation and rejection concept of immunotherapy

Suggested Readings

1. Delves PJ, Martin SJ, Burton DR, Roitt IM (2011) Roitt's Essential Immunology, 12th edition. Wiley-Blackwell

2. Owen J, Punt J, Stranford S (2012) Kuby Immunology, 7th edition. Macmillan Learning.
3. Janeway, Charles (2005) Immunobiology: The Immune System in Health and Disease, 6th edition. Garland Science Taylor & Francis Group
4. Rao CV (2002) An Introduction to Immunology, CRC Press
5. Kimball JW (1990) Introduction to Immunology. 3rd edition, Macmillan Publishing Corporation.
6. Luttmann W (2006) Immunology Experimenter series, Academic Press
7. Coico R, Sunshine G (2015) Immunology: A Short Course, John Wiley & Sons

ME342P. PRACTICALS BASED ON ME342 (1 Credit)

FOURTH SEMESTER

ME401. DISSERTATION/THESIS WORK (8 Credits)

ME402.PRESENTATION (2 Credits)