SIKKIM UNIVERSITY

Syllabus for M.Sc. in Environmental Sciences

The M.Sc. degree in Environmental Sciences is spread over four semesters. The entire programme comprises four different components viz (a) Teaching (b) Laboratory Work (c) Field Work and (d) Dissertation.

The total credits for M.Sc. in Environmental Sciences are 80 credits and 2000 Marks. The credits have been distributed as follows:

- Teaching = 48 credits
- Laboratory work = 12 credits
- Field work = 04 credits
- Dissertation = 16 credits

There are a total of 12 theory papers under teaching component in which 8 papers are core/compulsory and 4 papers are special/elective in nature. The department offers a basket of 12 Special/Elective papers over II and III semesters. The students can choose 4 special/elective papers from them. Distribution of credits among different papers are as follows:

1.	Core Theory Paper (8 Papers):	32 Credits	800 Marks
2.	Special (Elective) Paper (4 Papers):	16 Credits	400 Mark
3.	Core Practical Paper (3 Papers):	12 Credits	300 Marks
4.	Field Work:	04 Credits	100 Marks
5.	Dissertation:	16 Credits	400 Marks

Eligibility for the Admissions

Any undergraduate who has passed B.Sc./B.A.Sc./ B.Tech. / B.E./BCA with a minimum of 45% marks or equivalent GPA from any University/Institution recognized by UGC/AICTE having at least one of these subjects Physics/ Chemistry/ Biology/Maths at 10+2 level shall be considered for admission to M.Sc. Environmental Science

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List of Courses:

CORE THEORY PAPER:

- ENVS-PG-C101: Ecology, Environment and Biodiversity
- ENVS-PG-C102: Earth System Sciences
- ENVS-PG-C103: Environmental Chemistry and Pollution
- ENVS-PG-C104: Environmental Data Analysis
- ENVS-PG-C201: Remote Sensing and GIS
- ENVS-PG-C202: Energy and Environment
- ENVS-PG-C301: Environmental Law and Environmental Impact Assessment
- ENVS-PG-C302: Natural Hazards and Disaster Management

SPECIAL (ELECTIVE) PAPER:

- ENVS-PG-E001: Fundamentals of Glaciology
- ENVS-PG-E002: Glacier Hydrology and Monitoring Techniques
- ENVS-PG-E003: Glacier Processes
- ENVS-PG-E004: Methods and Techniques in Glaciology
- ENVS-PG-E005: Surface and Ground Water Hydrology
- ENVS-PG-E006: Integrated Water Resources Management
- ENVS-PG-E007: Watershed and Springshed Conservation and Management
- ENVS-PG-E008: Water Quality Analysis and Management
- ENVS-PG-E009: Environmental Physics
- ENVS-PG-E010: Atmospheric Processes
- ENVS-PG-E011: Air Pollution Chemistry
- ENVS-PG-E012: Climate Change and Its Impact

CORE PRACTICAL PAPER:

- ENVS-PG-P109: Practical I
- ENVS-PG-P209: Practical II
- ENVS-PG-P309: Practical III

CORE FIELD TRAINING

- ENVS-PG-F401: Field Training

DISSERTATION

- ENVS-PG-D402: Dissertation

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- **Distribution of Papers**

Semester I	**Semester II**	**Semester III**	**Semester IV**
Theory I (Core)	Theory V (Core)	Theory IX (Core)	Field Work
Theory II (Core)	Theory VI (Core)	Theory X (Core)	Dissertation
Theory III (Core)	Theory VII (Special)	Theory XI (Special)	
Theory IV (Core)	Theory VIII (Special)	Theory XII (Special)	
Practical I	Practical II	Practical III	

Course Details:

Paper	**Paper Title**	**Credit**	**Marks**
Semester I		**(4 core Paper)**	
ENVS-PG-C101	Ecology, Environment and Biodiversity	4	100
ENVS-PG-C102	Earth System Sciences	4	100
ENVS-PG-C103	Environmental Chemistry and Pollution	4	100
ENVS-PG-C104	Energy and Environment	4	100
ENVS-PG-P109	Practical I	4	100
Total		**20**	**500**
Semester II		**(2 Core and 2 Special Paper)**	
ENVS-PG-C201	Environmental Data Analysis	4	100
ENVS-PG-C202	Natural Hazards and Disaster Management	4	100
ENVS-PG-E00X	Special Paper I	4	100
ENVS-PG-E00X	Special Paper II	4	100
ENVS-PG-P209	Practical II	4	100
Total		**20**	**500**
Semester III		**(2Core and 2 Special Paper)**	
ENVS-PG-C301	Environmental Law and Environmental Impact Assessment	4	100
ENVS-PG-C302	Remote Sensing and GIS	4	100
ENVS-PG-E00X	Special Paper III	4	100
ENVS-PG-E00X	Special Paper IV	4	100
ENVS-PG-P309	Practical III	4	100
Total		**20**	**500**
Semester IV		**Field Training and Dissertation**	
ENVS-PG-F401	Field Training	4	100
ENVS-PG-D402	Dissertation	16	400
Total		**20**	**500**

DETAILED SYLLABUS

ENVS-PG-C101: Ecology, Environment and Biodiversity

Unit I: Ecology

Ecological terminology and definitions, Level of organization: habitat and niche, individual, species, population, Community, biome and ecosystem organization. Ecological Succession, Concept of ecosystem: Structures- biotic and abiotic components, Functions- energy flow, food chains, food webs. Productivity of ecosystem and ecological pyramids, terrestrial and aquatic ecosystems, population interactions. Biogeochemical cycles and hydrological cycles. Ecosystem degradation and restoration - factors/threats of ecosystem, restoration of ecosystem.

Unit II: Environment

Components and Importance. Human Impacts on Environment: various human activities like mining, construction and developmental projects, population growth on environment. Environmental Impact Assessment and Sustainable Development. Environmental Pollution: Types - Water, Land, Noise and Air pollution. Current Environmental Issues of Importance: Climate change, Global warming, ozone layer depletion, acid rain, urbanization. Environmental Protection: Laws, Role of Government and Initiatives by NGOs.

Unit III: Biodiversity

Introduction to biodiversity: species, genetic and ecosystem diversity. Biodiversity conservation, principles and strategies; in-situ and ex-situ conservation, Protected Area Network. Biodiversity Hotspots: concepts, distribution and importance as source of food, medicine, raw material, aesthetic and cultural. Threats to Biodiversity: Species extinctions and their drivers – deforestation, land use changes, overexploitation, biological invasions; habitat loss; Human intervention and Biodiversity loss: Global Environmental changes, land in water use changes.

Unit IV: Environmental Resources and Conservation

Types of Natural Resources: Renewable and Non-renewable resources, Mineral Resources and Environment: Resources and Reserves, Minerals and Population. Oceans as new areas for exploration of mineral resources. Ocean ore and recycling of resources. Environmental impact of exploitation. Processing and smelting of minerals. Water Resources and Environment: Global Water Balance. Ice sheets and fluctuations of sea levels. Origin and composition of seawater. Hydrological cycle. Factors influencing the surface water. Types of water. Resources of oceans. Human use of surface and ground waters.

Suggested Readings:

- E.P. Odum and G.W. Barrett. 2005. Fundamentals of Ecology. Cengage Learning India Pvt. Ltd.
- J.S. Singh, S.P. Singh and S.R. Gupta. 2008. Ecology, Environment & Resource Conservation. Anamaya Publications.

- V.H. Heywood and Watson R.T. (Ed). 1995. Global Biodiversity Assessment: UNEP. Cambridge University Press.
- Gaston, K J. & Spicer, J.I., 1998. Biodiversity: An Introduction, Blackwell Science, London, UK.
- Lovejoy, T. E. & Hannah, L. (eds), 2006. Climate change and Biodiversity, Yale Univ. Press, Yale.
- Odum E.P., 1996. Fundamentals of Ecology, Nataraj Publisher, Dehradun
- Kormondy E. J., 1994. Concepts of Ecology, Prentice Hall of India.
- Biodiversity Profile of India. ces.iisc.ernet.in/hpg/cesmg/indiabio.html

ENVS-PG-C102: Earth System Sciences

Unit-I Earth Processes

Origin of Earth, Geological Time Scale, Internal structure of earth, Classification of Rocks, Chemical and physical characteristics of layers, Introduction to plate tectonics. Introduction to Isotope systematics and application.

Unit-II Surface Process

Surface processes and its agents: Weathering, erosion, transportation. Principles of Geomorphology and landforms related to aeolian, fluvial, glacial, lacustrine and marine processes. Climate and tectonic geomorphology. Techniques of identification and quantification of geomorphological processes.

Unit-III Evolution of Earth System Science

The emergence and evolution of Earth System Science. Interaction of biosphere, cryosphere, hydrosphere, geosphere and atmosphere with human population. Timeline illustrating the development of Earth System Science from the mid-20th century. The NASA Bretherton diagram of the Earth System. Earth Observing System, (EOS) satellites and associated research Contemporary ESS (beyond 2015). The Amsterdam Declaration

Unit –IV ESS Tools and Approaches

ESS tools and approaches, Modelling the Earth System. Assessments and syntheses, New concepts arising from ESS, The Anthropocene, An updated conceptual model of the Earth System.

Suggested Readings:

- Press F. & Sievers R. Understanding Earth, W. H. Freeman; 4 edition (July 17,2003)
- Steffen, W., Richardson, K., Rockström, J. et al. The emergence and evolution of Earth System Science. Nat Rev Earth Environ 1, 54–63 (2020). https://doi.org/10.1038/s43017-019-0005-6
- Lovelock, J. Gaia: A New Look at Life on Earth (Oxford Univ. Press, 1979).
- National Research Council. Earth System Science. Overview: A Program for Global Change (National Academies Press, 1986).

- Bretherton, F. P. Earth system science and remote sensing. Proc. IEEE 73, 1118–1127 (1985).
- Kent C. Earth as an Evolving Planetary System, Academic Press; 3 edition (25 November 2015)
- Lenton Tim, Earth System Science: A Very Short Introduction Oxford University Press.
- Marshak Stephen 2018 Earth: Portrait of a Planet (Sixth Edition) : W. W. Norton & Company; Sixth edition:
- Carla Montgomery (2011) Environmental Geology, McGrew Hill, Ryerson
- Edward A. Keller (9th edition) Environmental Geology, Prentice Hall, USA
- Tom Garrison (2011) Essential of Oceanography, Brooks/Cole CENGAGE learning.

ENVS-PG-C103: Environmental Chemistry and Pollution

Unit I Concept

Stoichiometry, Gibbs' free energy, Chemical potential, Chemical equilibria, Acid base reactions, Solubility product, Solubility of gases in water, Henry's Law, Raoult's Law, Ionic Equilibria, Red-Ox reactions, Nernst Equation, pH, pE, Buffer Solutions, Unsaturated and saturated hydrocarbons, free radical reactions, Basic nuclear chemistry and Radionuclides. Basics of Photochemistry. Photo-chemical reactions. Chemical kinetics, rates of important environmental reactions. Fossil fuels: their types, properties, combustion and environmental implications.

Unit II Air and Water Chemistry

Air Chemistry: Classification of elements, Chemical speciation. Particles, ions and radicals in the atmosphere. Chemical processes for formation of inorganic and organic particulate matter. Thermochemical and photochemical reactions in the atmosphere. Primary and Secondary pollutants. Transport and diffusion of pollutants. Gas laws governing the behaviour of pollutants in the atmosphere. Oxygen and ozone chemistry, Chemistry of air pollutants, Photochemical smog.

Water Chemistry: Chemistry of water, concept of DO, BOD, COD, sedimentation. coagulation, filtration. Water cycle. Eutrophication, Role of soaps and detergents. Sewage and wastewater treatment

Effect of Toxic Chemicals on - Air, Water: Pesticides in water. Biochemical aspects of Arsenic. Cadmium. Lead. Mercury, Carbon monoxide. O_3 and PAN Pesticides. Insecticides, MIC, carcinogens in the air. Chlorofluorocarbons, Greenhouse gases, Acid rain.

Unit III Soil Chemistry and Case Studies

Soil Chemistry: Inorganic and organic components of soil, Nitrogen pathways and NPK in soils. chemistry of silicate and ore minerals; bulk composition of the earth, crust, clay and its composition. Industrial waste effluents and heavy metals; their interactions with soil components. Soil microorganisms and their functions. Degradation of different insecticides, fungicides and weedicides in soil, Solid Waste management.

Cases of atmospheric pollution – e.g. Bhopal Gas tragedy, Global warming, Minamata Disease, Effect of Arsenic in groundwater, ozone layer depletion, effect of plastic on aquatic life etc., pollution of major rivers-lifeline of India.

Unit IV Analytical Methods

Principles of Analytical Methods: Titrimetry, Gravimetry, Colourimetry, Spectrophotometry. Chromatography. Gas Chromatography, Atomic Absorption Spec-trophotometry, GLC, HPLC, Electrophoresis. X-ray fluorescence, X-ray diffraction, Flame photometry, Characterisation of Water, Air and Soil Pollutants, Basics of statistical tests for sampling -t-test, chi-square test, ANOVA.

Suggested Readings:

- Skoog Douglas A; Holler F James; Nieman Timothy A, Principles of Instrumental Analysis, Philadelphia: Saunders College Pub.; Orlando, Fla.: Harcourt Brace College Publishers, ©1998Principles of instrumental analysis
- Botkin, D. B. & Keler, E. A., Environmental Science, Earth as a Living Planet, 8th Ed, New Delhi: Wiley India Pvt. Ltd, 2011
- Rajagopalan R. Environmental Studies,3rd Edition, New Delhi: Oxford University Press, 2015
- Wright R.T. Environmental Science: Towards a Sustainable Future, New Delhi: PHL Learning Private Ltd., 2008
- Rao C. S. Environmental Pollution Control Engineering, 2nd Ed New Delhi: New Age International (P) Ltd., 2006
- Manahan S.E. Environmental Chemistry, Lewis, 1994
- De A.K. Environmental Chemistry, Wiley Eastern Limited, 2000
- Moore J. W. Inorganic Contaminants of Surface Water: Research and Monitoring Priorities, Springer-Verlag, New York: 1991
- Vigil K.M. Clean Water: An introduction to water quality and Water Pollution Control, Oregon State University Press, 2003
- Bell J. N. B. Air Pollution and Plant Life, 2nd Edition, John Wiley and Sons, 2002
- Fellenberg G. Chemistry of Pollution, John Wiley and Sons, 1999

ENVS-PG-C104: Environmental Data Analysis

Unit-I Basic Mathematics

Algebra: series and sequences, quadratic equation, complex numbers, matrices and determinants, concept of eigen value and eigen vectors.

Trigonometric and logarithmic function and their classic plots, standard function of line, circle, ellipse, parabola and hyperbola

Concept of co-ordinate systems (Cartesian, polar and spherical)

Basic concept of differentiation, integration, difference equation, differential equation and partial differential equation

Unit-II Fundamental of Statistics

Measures of central tendency. Measures of dispersion. Measures of skewness and kurtosis, Permutation and combination,
Probability- definition, addition and multiplication laws, concept of random variable. Probability distributions- normal, binomial, and poisons, Concept of Conditional probability and its application

Unit-III Geo-statistics
Sampling techniques. Sampling and Data analysis errors.
Univariate, Bivariate and Multivariate data characteristics and analysis, Ordinary least square estimation, Maximum likelihood estimation, Baye's theorem, Basics of Factor analysis, Principal Component analysis and cluster analysis.
Concept of regionalized variable, Basics of variogram & semivariogram construction and interpretation. Kriging, basics and applications

Unit-IV Computer Applications in EDA
Data visualization techniques using common applications like Excel, Grapher, Surfer. Introduction to R, S-Plus, SPSS, Spatial data visualization and analysis in GIS applications.

Suggested Readings:

- Webster and Oliver, Geostatistics for Environmental Scientists. 2007 John Wiley & Sons Ltd
- Klaus Knödel, Gerhard Lange, Hans-Jürgen Voigt. Environmental Geology Handbook of Field Methods and Case Studies. 2007. Springer
- Clarke, I., Practical Geostatistics, 2001.
- Zhihua Zhang., Environmental Data Analysis: Methods and Applications. Walter de Gruyter GmbH & Co KG, 2016
- Clemens Reimann, Peter Filzmoser, Robert Garrett, Rudolf Dutter. Statistical Data Analysis Explained: Applied Environmental Statistics with R. 2011. Wiley

ENVS-PG-C201: Remote Sensing and GIS

Unit I Remote Sensing
Definition, Sources of Radiations, Components of Remote Sensing, Energy, Sensor, Active and Passive Remote Sensing, Aerial and Space Platforms- Aircraft and Satellites, Electromagnetic Radiation (EMR), EMR spectrum. Interaction of EMR with atmosphere, earth surface, soil, water and vegetation, LANDSAT, SPOT, ERS, IKONOS and others, Indian Space Programme.

Unit II Geographic Information System
Geographical Information System (GIS): Components of GIS; Data input, Storage & output. Map projections and coordinate system, Survey of India base maps, Types of Maps, thematic maps, Data Acquisition and Digital Image Concepts, The Global Positioning System and Other Global Navigation Satellite Systems

Unit III Photogrammetry

Photogrammetry, scale of photographs, Terrestrial and aerial photographs, Scale, geometric characteristics, parallax, DEM, DTM, Stereoscopic vision and stereoscopies, Principle of photo interpretation, Visual and digital image interpretation, flight planning, height determination from parallax measurement,

Unit IV Digital Image Processing and Analysis

Satellite Data analysis, Visual interpretation via stereoscope, Digital image processing, Applications: Development of Watershed management, Drainage basins, Study of Stream geometry, and drainage patterns. Snow cover and glacier mapping, GLOF, Land Use/Land Cover Mapping, Environmental Assessment and Protection, Natural Disaster Assessment.

Suggested Reading:

- Thomas M Lillesand, and Rralph W Kiefer; "Remote sensing and Image Interpretation", JohnWiley& Sons, 1994, 3rd edition.
- Rampa K.K Handbook of Aerial photography and interpretation, Concept publishing company, New Delhi, 1996.
- Michael F. Worboys, GIS: A Computing Perspective", Taylor & Francis Ltd, 1995
- Campbell, J. B., Introduction to Remote Sensing, 1996
- Weng Q; Remote Sensing and GIS Integration, McGraw-Hill, 2009
- Ross S. Lunetta, John G. Lyon, Remote Sensing and GIS Accuracy Assessment, CRC Press, 2004
- John Stillwell, Graham Clarke, Applied GIS and Spatial Analysis, Wiely, 2003

ENVS-PG-C 202: Energy and Environment

Unit I Introduction

Energy sources, Forms of energy, different sources of energy, significance and its ultimate fate, Energy flow patterns, effects of energy use on the environment and analyses of current energy related issues, Global Energy production and consumption pattern, National Energy Scenario, Energy Policy of India, Energy and Power Auditing and Management, GRIHA and LEED Rating

Unit II Principles

Laws of thermodynamics and their applications, Carnot cycle and Carnot Efficiency, Entropy in energy production and distribution, Patterns of Energy acquisition and utilization in living systems. Energy Efficiency, Electric motors and generators, Environmental impact of energy production, distribution and use (Air, water, soil, noise and thermal pollution).

Unit III Types of Energy Resopurces

Conventional and Non-conventional energy resources, principles of generation and its environmental impact: coal, oil, biomass and natural gas, nuclear energy, fusion, fission, MHD

Renewable Energy resources, principles of generation and its environmental impact: hydroelectric power, tidal energy, wind energy, wave energy, OTEC, geothermal energy, photovoltaics, the solar collector, solar water heaters, solar ponds, solar farm, bioenergy.

Unit IV Impact

Energy use pattern in different parts of the world and its impact on the environment. CO_2 emission in atmosphere. Mechanism of radiation action on living systems- Stochastic and Non-stochastic effects; delayed effects, radioactivity from nuclear reactors, fuel processing and radioactive waste, hazards related to power plants, terrestrial and non-terrestrial radiation, dose from environment and nuclear radiations, ultraviolet radiations, pathways analysis and dose assessment.

Suggested Readings:

- Devins D.W., Energy: Its Physical Impact on the Environment, John Wiley and Sons, 1982.
- Fowler J.M., Energy and Environment, McGraw Hill, 1984.
- Ristinen R.A. and Kraushaar J.J., Energy and the Environment, John Wiley and Sons, 1998
- Peter E Hodgson, Energy, The Environment and Climate Change, Imperial College Press, 2010
- Energy and the Challenge of Sustainability, World Energy Assessment, UNDP, 2000. Rai G.D., Non –Conventional Sources of Energy, Khanna Publishers 1997.
- Ravindranath N.H., Usha Rao K., B.Natarajan and P. Monga Renewable Energy and Environment-A Policy Analysis for India, Tata- McGraw Hill,2000
- Nakicenovic N., (edt.) Global Energy Perspectives, Cambridge University Press, 1998
- Rai G.D., Non –Conventional Sources of Energy, Khanna Publishers 1997

Sustainable Development Strategies: A Resource Book. Organisation for Economic Co-operation and Development, Paris and United Nations Development Programme, New York

ENVS-PG-C301: Environmental Law and Environmental Impact Assessment

Unit I: Environmental Protection - issues and problems

National Environmental Policy, provisions for environment protection in the constitution of India; major environmental movements in India: Chipko movement, Narmada dam, Tehri dam, Almeti dam; Role of NGO's.

Unit - II: Environmental Laws

National Water Policy, Air Pollution Act (1981), Water Pollution Act (1974), Water Cess Act (1977), Environmental (Protection) Act (1986), Hazardous Wastes Management and Handling Rules (1989), Municipal Solid Waste (Management and Handling Rules) (2000), Scheme of labelling of environmentally friendly products (Ecomark). Public Liability Insurance Act, I991 and Rules 1991.Coastal Regulation Zones (CRZ) Rules (2011), Plastics Manufacture, Sale and Usage Rules (2011), Ecomark, Wildlife (Protection) Act (1972), Forest (Conservation) Act (1980), Biological Diversity Act (2002), Mining Act.

Unit - III: Environmental impact assessment (EIA)

Environmental impact statement (EIS), scope and types of environmental audit, environmental management plan (EMP), eco-management and audit scheme (EMAS), ISO standards. Environmental management plan (EMP), ISO standards, safety management system - EMS; Life Cycle Analysis (LCA) and its components.

EIA guidelines 1994, Notification of Government of India.

Unit - IV: International Efforts

UNEP, WWF, UNESCO, IGBP, IUCN, GEF, UNFCCC, IPCC, Stockholm Conference on Human Environment (1972), Nairobi Declaration, Montreal Protocol (1987), Basel Convention (1989 and 1992), Earth summit at Rio de Janeiro (1992), Kyoto Protocol (1997), Earth summit at Johannesburg (2002), CBD, Paris Declaration, UN Climate Action Summit, Sustainable Development Goals (SDG)

Suggested Readings:

- Lawrence D.P., Environmental Impact Assessment: Practical Solutions to Recurrent Problems, Wiley-Interscience, 2003
- Morris Peter and Therivel Riki, Methods of Environmental Impact Assessment, Routledge, 2001
- Craik Neil, The International Law of Environmental Impact Assessment: Process, Substance and Integration, Cambridge University Press, 2008
- Glasson J., Therivel R., Chadwick A.; Introduction to Environmental Impact Assessment: Principles and Procedures, Process, Practice and Prospects - 2nd ed., 2010
- Wathern P., Environmental Impact Assessment: Theory and Practice, Routledge, 1998
- Louka E., International environmental law, Cambridge University Press, Year: 2006

ENVS-PG-C302: Natural Hazards and Disaster Management

Unit I: Concept of Hazard and Disaster

Concept of hazard and disaster: nature, causes, risk, vulnerability, exposure and responses
Climate change and disaster,
Natural hazard profile of India,
Distinction between natural hazards and anthropogenic environmental disturbances,
Hybrid hazards,
Environmental Hazards: Classification, Causes and Distribution.

Unit II: Natural and Manmade Disasters

Geological **Disasters**: Earthquakes – a plate tectonic perspective and seismic micro zonation, Volcanoes – types and geographical distribution, Mass-movement. Landslides
Hydrometeorological **Disasters**: Floods, Droughts, Tsunami; Cyclones, Extreme weather events, Cloud-bursts, GLOF and Avalanches
Biophysical Hazards: Frost Hazards in agriculture, epidemics, wildfire.
Different type of Manmade and technological Disasters

Unit III: Disaster Management

Disaster management cycle

Disaster preparedness: preventive measures, early warning system, response and recovery

Impacts of disasters: health, physical and socio-economic.

Risk assessment and vulnerability analysis;

National preparedness and adaptation strategies;

Role of GIS and remote sensing in surveillance, monitoring, risk assessment, estimation of losses and planning.

Policy and Act: NDMA, SDMA, Sendai Declaration, UN-SPIDER

Unit IV Case Studies

Study of major disasters in human history and lessons learnt

Suggested Readings

- Allen, S.K., Linsbauer, A., Randhawa, S.S., Huggel, C., Rana, P. and Kumari, A. 2016. Glacial lake outburst flood risk in Himachal Pradesh, India: an integrative and anticipatory approach considering current and future threats. *Natural Hazards*, 84: 1741-1763.
- Mukherjee, S. Earthquake Prediction, Brill Academic Publishers Koninklijke Brill NV, Leiden (The Netherlands) & Boston (USA), 2016
- Bell, F.G. 2003. Geological Hazards: Their Assessment, Avoidance and Mitigation. CRC Press.
- Bilham, R. 2004. Earthquakes in India and the Himalaya: tectonics, geodesy and history. Annals of Geophysics, 47(2-3).
- Blaikie, P., Cannon, T., Davis, I. and Wisner, B. 2014. At Risk: Natural Hazards, People's Vulnerability and Disasters. Routledge.
- Burton, I. The Environment as Hazard. Guilford Press,1993
- Margottini, C. and Casale, R. 2004. Natural disasters and sustainable development. Environmental Science Series, Springer.
- Hewitt. K. 1997. Regions of Risk, Longman Press.Henry J.G. and Heinke , G.W. 2004, Environmental Science and engineering, Pearson education, Delhi, India.
- Shroder, J. & Wyss, M. (eds). 2014. Earthquake Hazard, Risk and Disasters (1st Edition). Elsevier. Smith, K. 2003. Environmental Hazards: Assessing Risk and Reducing Disaster. Routledge.
- Tewari, V.C. 2014. Recent natural disaster in the Uttarakhand Himalaya and future geotechnical remedial measures. *Journal. Geological. Society of India*, 84 (1),125- 126.

ENVS-PG-E001: Fundamentals of Glaciology

Unit 1: Origin and Distribution of Seasonal Snow and Glaciers.

Causes of glacial-interglacial periods: endogenic forces- continental shifting, highlands and mountain uplifts, isostatic depression and uplift of crust, ocean current and planetary wind

system, precipitation. Exogenic forces: relation of climatic fluctuation to solar activity: sunspot: -the effect of geometric variation in elements of earth's orbit.

Paleoglaciation: Major events of past glaciations on Earth, dating of glaciogenic deposits, dating of ice cores, other dating techniques.

Importance of Snow and Glaciers, World distribution of existing snow and glaciers

Remote sensing missions and the cryosphere: Satellites, Sensors, Snow and Glacier Products

UNIT II: Snow and Permafrost

Snow: - snow formation and growth in the atmosphere, snow metamorphism, snowpack temperature and temperature gradients, dry metamorphism, properties of wet snow, metamorphism of wet snow, classification of snow. Snow studies for Avalanche investigations in India.

Permafrost: Introduction to permafrost and related terminology, occurrence and distribution, global and local relevance, methods for permafrost detection, mapping and monitoring, status of permafrost in the Himalayas

Unit III: Glacier

Glacier geomorphology: Features of a glacier, Glacier influences on the landscape: Erosion, Deposition and Transportation with special emphasis on mountain/valley glaciers. Glacier hazards, instabilities-glacier surge.

Ice Volume, Water Storage, Glaciers as a source of water in the Himalaya

Procedure for glacier inventory: glacier data sheet and source, Glacier identification system: methodology /glacier delineation, glacier volume estimation, glacier ice depth estimation, glacier classification and description: the World Glacier Monitoring Service (WGMS) glacier classification system, the Global Land Ice Measurements from Space (GLIMS) and Randolph Glacier Inventory (RGI) glacier classification system, other contemporary glacier outline extraction methods: manual digitization, snow-and-ice mapping methods, generation of DEMS from stereo images, glacier surface velocities, use of thermal imaging to aid interpretations.

Unit IV: Cartography and Cryosphere-Climate and Society Linkages

Fundamentals of Cartography, Concept and application of Scales, Map Projections –Polar Zenithal Stereographic, Bonne's, Mercator's Projection, Universal Transverse Mercator (UTM) Projection. Application of projections on satellite imageries. Interpretation of Topographical Map – Interpretation of a glacierised terrain. Geomorphological mapping-mapping glaciers and glacial landforms.

Cryosphere -Climate and Society Linkages: Introduction to pathways adopted by the IPCC for climate modelling and research (RCP). Influences of Cryosphere (ecology, micro-climate, hydrology, hazards) on Socio, Economic (Agriculture, Livestock, Tourism) and non-economic system (Spiritual, Cultural, Religion, Community Relationship) especially in Sikkim. Case studies from Ladakh, Sikkim around the world on various snow and glacier geo-engineering and water/hazard management techniques.

Suggested Reading:

- Glacier Curriculum jointly compiled by the Swiss Agency for Development and Cooperation (SDC) and The Department of Science and Technology (DST), Government of India. http://glaciology.in/
- Bennett, M.R., Glasser, N.F. Glacial geology: ice sheets and landforms. Wiley Press.
- Hubbard, B. D., & Evans, D. J. A. (2010). Glaciers and Glaciation (2nd ed.). Hodder Arnold Publication. Routledge.
- Jouzel, J. (2013). The White Planet: The Evolution and Future of Our Frozen World. Princeton University Press.
- Parry, J. L., & Tranter, M. (2012). The Ecology of Snow and Ice Environments Oxford University Press.
- Slaymaker, O., & Kelly, R. (2005). The Cryosphere and Global Environmental Change. Blackwell Publishing
- Alley, R. (2011). K.M. Cuffey and W.S.B. Paterson. 2010. The physics of glaciers. Fourth edition. Amsterdam, etc., Academic Press.
- Racoviteanu, A.E., Williams, M.W. and Barry, R.G. 2008b. Optical remote sensing of glacier characteristics: a review with focus on the Himalaya. Sensors, 8 (5), 3355–3383.
- Kulkarni, A. V. 1988. A field study of snow cover albedo on the Chota Shigri Glacier, H.P. Ahmedabad, Space Applications Centre. (Technical note No. SAC/RSA/RSAG-MWRD/TN/01/88.) Google Scholar
- Gupta K.K. and Tyagi, V. C., 1992: Working with Map, Survey of India, DST, New Delhi.
- Mishra R.P. and Ramesh, A., 1989: Fundamentals of Cartography, Concept, New Delhi.
- Monkhouse F. J. and Wilkinson H. R., 1973: Maps and Diagrams, Methuen, London.
- Rhind D. W. and Taylor D. R. F., (eds.), 1989: Cartography: Past, Present and Future, Elsevier, International Cartographic Association.
- Kulkarni, A. V. and Narain, A. 1990. Remote sensing based glacier inventory in the Sikkim state, presented at Regional Workshop on IRS-IA Mission and its Application Potential. Gangtok, Sikkim.
- Sangewar CV, Shukla SP (2009) Inventory of the Himalayan glaciers: a contribution to the international hydrological programme. Special Publication, Geological Survey of India, 34: An Updated Edition (594 pp)
- World Glacier Monitoring Service (WGMS) (2008a) Global glacier changes: facts and figures.UNEP, World Glacier Monitoring Service, Zürich http://www.grid.unep.ch/glaciers/
- Arendt, AA and 77 others (2012) Randolph Glacier Inventory [v2.0]: A Dataset of Global Glacier Outlines. Global Land Ice Measurements from Space, Boulder, CO http://www.glims.org/RGI/randolph.html

ENVS-PG-E002: Glacier Hydrology and Monitoring Techniques

Unit I: Water Bodies associated with Glaciers

Concept of Watersheds and Drainage basins, River Drainage System, Water divides, Ground water, streams, springs and high-altitude lakes.

Influence of Climate Change and Anthropogenic activities on water resources. Hazards: Glacial Lake Outburst Floods, landslides, flooding, lake pollution, river contamination and mitigation strategies.

Unit II: Snow and Glacier Melt and Runoff

Snow and Glacier runoff model in Himalaya

Water balance of a glacierized catchment, contribution of melt to stream flow, impact of Climate Change on Water Resources.

Discharge measurement methods: Runoff measurements, water level measurements, area velocity method, current metre, velocity sensor, tracer methods. Sediment load study in a glacierised terrain.

Introduction to Isotope Analysis to understand contribution of snow, precipitation to runoff.

Unit III: Remote Sensing methods to estimate Snow Cover and hands on exercises

Spectral reflectance of snow and ice, Different methods to estimate snow cover, Scientific basis of snow mapping (NDSI).

Exercises on the: Algorithms to extract snow cover.

Unit IV: Remote sensing methods to estimate glaciers and hands on exercises

Satellite instruments for glacier research, Image classification for glacier mapping, Mapping debris-covered glaciers, Glacier mapping with SAR data, Assessing glacier changes, Area and length changes, Volumetric glacier changes, Glacier velocity.

Exercises on interpretation of Satellite Imageries – Delineation of snow and glaciers on satellite images using band ratios and semi-automatic techniques. Scientific basis of glacier mapping and methods to estimate glacier retreat.

Suggested Readings:

- Glacier Curriculum jointly compiled by the Swiss Agency for Development and Cooperation (SDC) and The Department of Science and Technology (DST), Government of India. http://glaciology.in/
- Bloom A. L., 2003: Geomorphology: A Systematic Analysis of Late Cenozoic Landforms, Prentice-Hall of India, New Delhi.
- Bridges E. M., 1990: World Geomorphology, Cambridge University Press, Cambridge.
- Knighton A. D., 1984: Fluvial Forms and Processes, Edward Arnold Publishers, London.
- Thornbury W. D., 1968: Principles of Geomorphology, Wiley.
- Fundamentals of Remote Sensing. Third Edition. By George, Joseph and Jeganathan, C. Universities Press (India) Private Limited, Hyderabad, India. 2018.
- Modern method of flow measurement. Prof B.S Thandaveswara. Indian Institute of Technology – Chennai.
- Bajracharya, SR and Mool, P (2009). Glaciers, glacial lakes and glacial lake outburst floods in the Mount Everest region, Nepal. Ann. Glaciol.,, 50(53), 81–86 (doi: 10.3189/172756410790595895)

- Basnett S., Kulkarni A.V., Bolch T. The influence of debris cover and glacial lakes on the recession of glaciers in Sikkim Himalaya, India J. Glaciol., 59 (218) (2013), pp. 1035-1046
- Dozier, J., Spectral signature of alpine snow cover from the Landsat Thematic Mapper, Remote Sens. Environ., 28, 9–22, 1989.
- Hall, D. K., Riggs, G. A., Salomonson, V. V., 1995a, Development of methods for mapping global snow cover using moderate resolution imaging spectroradiometer data. Remote Sensing of Environment, 54, pp. 127–140.
- Kulkarni, A. V., Srinivasulu, J., Manjul S.S., Mathur. P., 2002. Field based spectral reflectance to develop NDSI method for snow cover monitoring. Journal of the Indian society of remote sensing, 30, pp. 73-80.
- Kulkarni.A.V., Singh S.K, Mathur P. and Mishra V.D.2006. Algorithm to monitor snow cover using AwiFs data of RESOURCESAT-1 for the Himalayan region.International Journal of Remote Sensing.Vol.27,No.12,pp. 2449-2457.
- Martinek J., Rango A., Roberts R. 2008. Snowmelt Runoff Model (SRM) User's Manual.
- Kulkarni, A.V., Randhawa, S.S., Rathore, B.P. et al. Snow and glacier melt runoff model to estimate hydropower potential. J Indian Soc Remote Sens 30, 221–228 (2002). https://doi.org/10.1007/BF03000365
- Bookhagen B, Burbank DW (2010) Toward a complete Himalayan hydrological budget: Spatiotemporal distribution of snowmelt and rainfall and their impact on river discharge. J Geophys Res 115:1–25

ENVS-PG-E003: Glacier Processes

Unit I: Introduction: Glacier Mass Balance

Mass balance of a glacier and related terms (e.g. ELA, AAR, mass balance gradient), Methods: Direct glaciological method, Geodetic Method, Hydrological Method, Temperature Index Model, Linear Mass Balance Model, Energy Mass Balance Model.

Unit II: Glacier Dynamics and Glacier Climate Relationship

Glaciers in equilibrium state, glacier mass balance and flow, mass balance and climate regime. Glacier Dynamics: Ice flow and geometry- ice flow, glacier flow, ice deformation, glen's flow law, crevasses formation.

Glacier-Climate relationship: Glacier length changes due to climate shift, response time, glacier surface evolution, advance and retreat, numerical glacier flow model.

Unit III: Energy balance over snow and ice

Radiation: Shortwave and longwave radiation, Net radiation, Albedo. Temperature: Surface and subsurface, cold content of snow and ice. Relative humidity, atmospheric pressure and wind. Turbulent fluxes: Sensible and latent heat flux, ground heat flux. Surface Energy Budget. The energy available for melting. Modelling the melt

UNIT IV: Exercises on Glacier Mass Balance

Exercises on Remote Sensing techniques to estimate glacier mass balance, Mass balance using AAR method

Suggested Readings:

- Bamber, J. L., & Payne, A. J. (2004). *Mass Balance of the Cryosphere: Observations and Modelling of Contemporary*. Cambridge University Press.
- Glacier Curriculum jointly compiled by the Swiss Agency for Development and Cooperation (SDC) and The Department of Science and Technology (DST), Government of India. http://glaciology.in/
- Tangborn W. V., Krimmel R M. and Meier M F (1975). A comparison of glacier mass balance by glaciological, hydrological and mapping methods, South Cascade Glacier, Washington, International Association of Hydrological Sciences Publication. 104, 185-196
- Chaturvedi R K, Kulkarni A, Karyakarte Y, Joshi J and Bala G 2014 Glacial mass balance changes in the Karakoram and Himalaya based on CMIP5 multi-model climate projections Clim. Change 123 315–28.
- Jonathan L. Bamber, Andres Rivera, A review of remote sensing methods for glacier mass balance determination, Global and Planetary Change, Volume 59, Issues 1–4, 2007, Pages 138-148
- Alley, R. (2011). K.M. Cuffey and W.S.B. Paterson. 2010. The physics of glaciers. Fourth edition. Amsterdam, etc., Academic Press.
- Jordan, R. E., Andreas, E. L., & Makshtas, A. P. (1999). Heat budget of snow-covered sea ice at North Pole 4. Journal of Geophysical Research, 104(C4), 7785– 7806.
- Azam MF, Wagnon P, Patrick C, Ramanathan A, Linda A, Singh VB, Vincent C, Ramanathan A, Linda A, Singh VB (2014) Reconstruction of the annual mass balance of Chhota Shigri glacier, Western Himalaya, India, since 1969. Ann Glaciol 55:69–
- Immerzeel WW (2010). Climate change will affect the Asian water towers. Science 328:1382–1385
- Oerlemans, J. (2001). Glaciers and Climate Change.CRC Press.
- Dobhal DP, Kumar S, Mundepi AK (1995) Morphology and glacier dynamics studies in monsoon-arid transition zone: an example from Chhota Shigri glacier, Himachal-Himalaya, India. Curr Sci 68:936–944
- Alley, R. (2011). K.M. Cuffey and W.S.B. Paterson. 2010. The physics of glaciers. Fourth edition. Amsterdam, etc., Academic Press.

ENVS-PG-E004: Methods and Techniques in Glaciology

Unit I: Use of Field Tools

Functioning and principle of different field equipment viz. GPS, GPR, Electrical Resistivity Meter, DGPS, Spectroradiometer, AWS, Sediment sampler, Ice Steam Driller, Ice drilling.

Unit II: Design and Planning of Fieldwork

Aim, Designing and planning field-based research, Logistical preparations for fieldwork, Acclimatization, First Aid Techniques, Medicines, Mountain Culture. Mountaineering and

climbing techniques (e.g. use of ropes, safety), Introduction to gear used in glacier study – Crampons, mountaineering boots, Clothes and layering. Narratives of glacier expeditions - Himalaya, Antarctic, Artic, Field sampling and analysis

Unit III: Remote Sensing Techniques

Exercises on Glacier Depth estimate using different techniques, Topographic corrections of reflectance, Estimation of supra glacier debris cover, Snow and Glacier runoff model in Himalaya, Runoff estimate in Himalaya.

Unit IV: Field Techniques

Exercises on field measurement of surface properties, sub-surface properties, topography, snow depth, snow water equivalent and density, temperature, albedo, stratigraphy. Exercises on discharge measurement from snow and precipitation

Suggested Readings:

- Hubbard Bryn and Glasser Neil, Field Techniques in Glaciology and Glacial Geomorphology, John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England
- Marco Tedesco, 2014. Remote Sensing of the Cryosphere. Wiley
- Bamber, J. L., & Payne, A. J. (2004). *Mass Balance of the Cryosphere: Observations and Modelling of Contemporary*. Cambridge University Press.
- Glacier Curriculum jointly compiled by the Swiss Agency for Development and Cooperation (SDC) and The Department of Science and Technology (DST), Government of India. http://glaciology.in/
- Fundamentals of Remote Sensing. Third Edition. By George, Joseph and Jeganathan, C. Universities Press (India) Private Limited, Hyderabad, India. 2018.

ENVS-PG-E005: Surface and Ground Water Hydrology

Unit I: Hydrological Cycle and Precipitation

Hydrological cycle, Hydrological budget, Hydro meteorological observation, Precipitation, Types and Forms, Measurement, Processing and measurement of missing precipitation data.

Unit II: **Hydrological Processes of Abstraction**

Water losses, Initial abstraction, interception and Depression storage, Evaporation, Evapotranspiration and infiltration, Field Measurement, Estimation by empirical formulae

Unit III: Runoff Process

Runoff, components of runoff, Factors affecting Runoff, Hydrograph, hydrograph separation, Unit hydrograph, Instantaneous unit hydrograph, Synthetic unit hydrograph, rainfall-runoff models – SCS method – Yield Estimation.

Unit IV: Groundwater and Well Hydraulics

Origin of groundwater, Rock properties affecting groundwater, Types of aquifer, Darcy's law, coefficient of permeability, groundwater flow rates, permeability formulae, laboratory and

field measurement of permeability, Groundwater movement, General flow equation, Steady and unsteady flow, well flow near aquifer boundaries, partially penetrating wells, characteristics of well losses, specific capacity, Safe yield, Ground Water Assessment.

Suggested Readings

- Warren Viessman, et al., Introduction to hydrology, Thomas Y. Crowell, New York, 1972
- Ven Te chow (editors), Handbook of applied hydrology, McGraw Hill Book company 1964.
- Subramanya K., Hydrology,Tata McGraw Hill Co., New Delhi, 1994.
- Patra. K.C, Hydrology and Water Resources Engineering, Narosa Publications, 2008, 2nd Edition, New Delhi.
- Jeya Rami Reddy. P, Hydrology, Laxmi Publications, New Delhi, 2004.

ENVS-PG-E006: Integrated Water Resources Management

Unit I: Context for IWRM

Water as a global issue: key challenges and needs, Definition of IWRM within the broader context of development, Complexity of the IWRM process, examining the key elements of IWRM process.

Unit II: Water Economics

Economic view of water issues: economic characteristics of water goods and services, Non-market monetary valuation methods, Water economic instruments, policy options for water conservation and sustainable use – Case studies. Pricing: distinction between values and charges, Private sector involvement in water resources management: PPP objectives, PPP options, PPP Processes, PPP experiences through case studies – Links between PPP and IWRM.

Unit III: Water Supply and Health Within the IWRM Consideration

Links between water and human health: options to include water management interventions for health, Health protection and promotion in the context of IWRM, Health impact assessment of water resources development.

Unit V: Water Legal and Regulatory Settings

Basic notion of law and governance: principles of international and national law in the area of water management. Understanding UN law on non-navigable uses of international water courses, Development of IWRM in line with legal and regulatory framework.

Suggested Readings:

- Technical Advisory Committee, Integrated Water Resources management, Technical Advisory Committee Background Paper No: 4. Global water partnership, Stockholm, Sweden. 2002.

- Technical Advisory Committee, Poverty Reduction and IWRM, Technical Advisory Committee Background paper no: 8. Global water partnership, Stockholm, Sweden, 2003.
- Technical Advisory Committee, Regulation and Private Participation in Water and Sanitation section, Technical Advisory Committee Background Paper No:1. Global water partnership, Stockholm, Sweden, 1998.
- Technical Advisory Committee, Dublin principles for water as reflected in comparative assessment of institutional and legal arrangements for Integrated Water Resources Management, Technical Advisory Committee Background paper No: 3. Global water partnership, Stockholm, Sweden. 1999.
- Technical Advisory Committee, Water as social and economic good: How to put the principles

ENVS-PG-E007: Watershed and Springshed Conservation and Management

Unit I: Watershed and Springshed Concepts

Watershed-Need for an Integrated Approach, Influencing Factors: Geology, Soil, Morphological Characteristics, Toposheet, Delineation, Codification, Prioritization of Watershed and Indian Scenario, and Hydrogeology of springs and integrated approach for Springshed management

Unit II: Soil Conservation Measures

Types of Erosion, Water and Wind Erosion: Causes, Factors, Effects and Control, Soil Conservation Measures: Agronomical and Mechanical, Estimation of Soil Loss, Sedimentation

Unit III: Water Harvesting and Conservation

Water Harvesting Techniques, Micro-Catchments, Design of Small Water Harvesting Structures Farm Ponds, Percolation Tanks, Rooftop harvestings, Design of recharge shafts. Planning of spring conservation measures in the recharge area with the help of community participation

Unit IV: Watershed and Springshed Management

Project Proposal Formulation, Watershed Development Plan- Entry Point Activities, Estimation, Watershed Economics, Agroforestry, Grassland Management, Wasteland Management – Watershed Approach in Government Programmes, Evaluation of Watershed Management, Springshed development: conflicts, challenges and community participation, Hydrogeological mapping of Springshed.

Suggested Reading

- Ghanashyam Das, Hydrology and Soil Conservation engineering, Prentice Hall of India Private Limited, New Delhi, 2000.
- Glenn O. Schwab, Soil and Water Conservation Engineering, John Wiley and Sons, 1981.

- Gurmail Singh, A Manual on Soil and Water Conservation, ICAR Publication New Delhi, 1982.
- Suresh, R. Soil and Water Conservation Engineering, Standard Publication, New Delhi, 1982.
- Vir Singh, Raj, Watershed Planning and Management,Yash Publishing House,Bikaner, 2000.
- Brooks, K. N., P. F. Ffolliott, H. M. Gregersen and L. F. DeBano. 1997. Hydrology and the Management of Watersheds. Second Edition. Iowa State University Press. Ames, Iowa. 502 pp. Heathcote, I. W. Integrated Watershed Management: Principles and Practice. 1988. John Wiley and Sons, Inc., New York.
- Heathcote, I. W. Integrated Watershed Management: Principles and Practice. 1988. John

ENVS-PG-E008: Water Quality Analysis and Management

Unit I: Water Quality

Physical and chemical properties of water, Suspended and dissolved solids, EC and pH major ions. Water quality investigation, Sampling design, Samplers and automatic samplers, Data collection platforms, Field kits, Water quality data storage, analysis and inference, Software packages, Principles of water quality, Water quality classification, Water quality standards, Water quality indices.

Unit II: Irrigation Water Quality

Water quality for irrigation, Salinity and permeability problem, Root zone salinity, Irrigation practices for poor quality water, Saline water irrigation, and Future strategies, Canal /Tube well irrigation for more production of food grains and its implication on the Water Resources and Global Carbon Foot printing.

Unit III: Water Pollution

Sources and Types of pollution, Organic and inorganic pollutants, BOD-DO relationships, impacts on water resources, NPS pollution and its control, Eutrophication control, Water treatment technologies, Constructed wetland.

Unit IV: Recycling and Reuse of Water

Multiple uses of water, Reuse of water in agriculture, Low cost wastewater treatment technologies, Economic and social dimensions, Packaged treatment units, Reverse osmosis and desalination in water reclamation.

Suggested Reading:

- George Tchobanoglous, Franklin Louis Burton, Metcalf & Eddy, H. David Stense, Wastewater Engineering: Treatment and Reuse, McGraw-Hill, 2002.
- Vladimir Novonty, Water Quality: Diffuse pollution and watershed Management, 2 and edition, John Wiley & Sons. 2003

- Mackenzie L Davis, David A Cornwell, Introduction to Environmental Engineering, McGraw- Hill 2006.
- Stum, M and Morgan, A., Aquatic Chemistry, Plenum Publishing company, USA, 1985.
- Lloyd, J.W. and Heathcote, J.A., Natural inorganic chemistry in relation to groundwater resources, Oxford University Press, Oxford, 1988. 4. Preliminary consolidated Report on Effect of climate change on Water Resources, GOI, CWC, MOWR, 2008.

ENVS-PG-E009: Environmental Physics

Unit I Fundamentals

Scalar and Vector, Laws of Motion, Friction and Air Resistance, concepts of Gravity, Central Forces, Coriolis Force, Angular Momentum, Moment of Inertia, Terminal Velocity and Settling Velocity, Wave Characteristics, Acoustic Waves, Electric Charge and Current, Electromagnetic Field and Potential, The Earth's Magnetic Field, Electromagnetic Induction.

Unit II Thermodynamics and Electromagnetic Radiation

Heat Transfer and Storage: Conduction, Convection, Radiation, Phase Change, The Heat Diffusion Equation, Heat Storage.

Principles of Thermodynamics: First and Second Laws, Heat and Work; Work Efficiency, Concept of enthalpy, entropy and free energy, Loss of Exergy in Combustion, Refrigeration and heat pumps, Thermal power stations, Geothermal power

Radiation: the electromagnetic spectrum, Transmission, absorption and reflection, Black body radiation, Biological effects of non-ionising radiation, Heat balance in animals, plants and buildings.

Unit III Natural Energy Production and Storage

Energy in the biosphere: Photosynthesis, Trophic levels, Other biological energy sources, Biomass energy; Concept of kinetic energy and potential energy, Energy storage, Electric motors and generators.

Unit IV Waves and Atoms

Sound Waves, Doppler Effect, Wave functions, Propagation of sound over distance, Concept of ultra sound and applications.

The structure of the atom, Atomic mass and energy, Isotopes, Binding energy and mass defects, Radioactive decay, Radioactive decay chains, Decay rates and half-lives; Biological impacts of ionising radiation, Radiation doses and dose limits, Environmental pathways of radioisotopes; Carbon dating and other radiometric dating techniques.

Suggested Readings:

- Smith C., Environmental Physics [1ed.], Routledge Introductions to Environment, London

- Boeker E. and Grondelle R.V. Environmental Physics**:** Sustainable Energy and Climate Change, Third Edition, *VU, University Amsterdam*, A John Wiley & Sons, Ltd., Publication
- Faraoni V., Exercises in Environmental Physics (2006) (en) (330s) [1 ed.], Springer
- Takeuchi Y., Iwasa Y., Sato K. (Eds.), Mathematics for Ecology and Environmental Sciences [1 ed.], Springer
- Forinash K., Foundations of Environmental Physics: Understanding Energy Use and Human Impacts [1 ed.], Island Press
- Campbell G.S., Norman, J.M., An Introduction to Environmental Biophysics, 2e, Springer-Verlag, New York, 1997
- Hillel Rubin and Joseph Atkinson, Environmental Fluid Mechanics, Marcel Dekker, Inc., 2001
- Iqbal M., Introduction to solar Radiation, Academic press, 1983

ENVS-PG-E010: Atmospheric Processes

Unit I Fundamental Processes

Thermal structure of the atmosphere and its composition. Radiation: basin Laws - Rayleigh and Mie scattering, multiple scattering, radiation from the sun, solar constant, effect of clouds, surface and planetary albedo. Emission and absorption of terrestrial radiation, radiation windows, radiative transfer, Greenhouse effect, Net radiation budget

Thermodynamics of dry and moist air: specific gas constant, Adiabatic and iso-entropic processes, entropy and enthalpy, Moisture variables, virtual temperature; Clausius – Clapeyron equation, adiabatic process of moist air, thermodynamic diagrams

Unit II Dynamic Meteorology

Dynamic Meteorology: Fundamental forces: Pressure, gravity, centripetal and Coriolis forces, continuity equation in Cartesian and isobaric coordinates. Momentum equation Cartesian and spherical coordinates; scale analysis, inertial flow, geostrophic and gradient winds, thermal wind; Potential vorticity, stream function and velocity potential; Concept of Rossby, Richardson, Reynolds and Froude numbers.

Unit III Atmospheric turbulence

Mixing length theory, planetary boundary layer equations, surface layer, Ekman layer, eddy transport of heat, moisture and momentum, Richardson criterion; Linear Perturbation Theory: Internal and external gravity waves, inertia waves, gravity waves, Rossby waves, wave motion in the tropics, baroclinic instabilities.

Unit IV State of Atmosphere and Cloud

Hydrostatic equilibrium**:** Hydrostatic equation, variation of pressure with height, geopotential, standard atmosphere, altimetry. Vertical stability of the atmosphere: Dry and moist air parcel and slice methods. Tropical convection.

Cloud Physics: Cloud classification, condensation nuclei, growth of cloud drops and ice-crystals, precipitation mechanisms: Bergeron, Findeisen process, coalescence process –

Precipitation of warm and mixed clouds, artificial precipitation, hail suppression, fog and cloud dissipation

Suggested Readings:

- Lutgens, F., Tarbuck, E., and Tasa, D, The Atmosphere: An Introduction to Meteorology. Pearson Publisher, 2009
- An Introduction to Atmospheric Physics, Second Edition, David G. Andrews, Cambridge University Press, 2010.
- Wallace and Hobbs, Introduction to Atmosphere: An Introductory Survey, Elsevier, 2006
- Thompson R. D., Atmospheric Processes and Systems, Routeledge, 2002.
- Reist, Parker C., Introduction to aerosol science. MacMillan Publishers, 1984.
- Rudiman, W.F., 2001. Earth's climate: past and future. Freeman Publisher.
- Rohli, R.V., and Vega, A.J., Climatology. Jones and Barlatt, 2007
- Aguado, E., and Burt, J., 2009. Understanding weather.
- Jacobson Mark, Fundamentals of Atmospheric Modelling, Cambridge University Press, 2005

ENVS-PG-E011: Air Pollution Chemistry

Unit I Introduction

Detention of Air pollution, Pollutants and Contaminants, Sources of air pollution. Types of air pollutants, organic and inorganic pollutants, their behaviour and fate on local, regional and global scale, monitoring of criteria and non-criteria pollutants. Effects of air pollutants on human health, plants, animals and materials.

Unit II Aerosols and Air pollution Meteorology

Aerosols, mass size and number distribution, Concept of elastic and inelastic scattering, Chemical composition of Aerosols, EC, OC, and BC and their impact.

Air pollution meteorology: Partial pressure, mixing ratio, Mixing heights, Wind roses, Inversion conditions, Stability of the atmosphere and pollutants, Plume behaviour, Air pollution dispersion, Long range transport.

Unit III Photochemistry

Fundamentals of photochemistry, Principle, fate of excited molecules. Chemistry of trace gases – No_x, SO_x, Ozone, Hydrocarbon, Chemistry of smog, Chemistry of PoPs in the atmosphere and their fate. The Hydroxy radical and oxidants. Stratospheric and tropospheric ozone chemistry. Atmospheric chemistry of climate forcing gases and particles. Basic atmospheric chemistry models, Land-atmosphere-ocean interactions of air pollutants, Gas to particle conversion.

Unit IV Global Air Pollution Issues

Ozone depletion, Acid rain, Greenhouse effect, Formation of photochemical smog, CFC, their nomenclature, sources and effect, Atmospheric Brown Cloud

Air pollution control mechanism: Adsorptions, Absorption and condensation techniques, Cyclone precipitator, Bag House Filter, Electrostatic precipitators, Venturi scrubbers.
Air pollution control technologies: Concept of clean environment, Green technologies, Carbon sequestration, Chemical methods.

Suggested Readings:

- Finlayson-Pitts and Pitts, Chemistry of the Upper and Lower Atmosphere, Academic Press, 2000 2.
- Jacob D. J, Introduction to Atmospheric Chemistry, Princeton, 2004
- Pluschke Peter; Indoor Air Pollution (Handbook of Environmental Chemistry), Springer, 2011
- Leighton Philip A; Photochemistry of Air Pollution, Academic Press, 1961
- John H. Seinfeld; Spyros N Pandis, Atmospheric Chemistry and Physics: from Air Pollution to Climate Change, Wiley-Interscience, 2006
- Harrison R M, Hester R E, Barbour A K, Burdett N A, and Jr J C.; Air Pollution & Health, Royal Society of Chemistry, 1998

ENVS-PG-E012: Climate Change and Its Impact

Unit I Concept of Climatology

Fundamental principles of climatology, Elements of climate, climate controls, Earth's radiation balance, Spatiotemporal variation of insolation, temperature, pressure, wind belts, humidity, cloud formation and precipitation, global hydrological cycle, water balance.

Unit II Air Parcel and Climatic Classification

Air masses and fronts, SW and NE monsoon, jet stream, tropical and extratropical cyclone, ENSO, QBO. Classification of climate- Koppen's and Thornthwaite's scheme. Movement in the atmosphere: global scale, regional scale, local scale, Oceans: General circulation patterns. Air- Sea interaction.

Unit III Climate feedback mechanism and Paleoclimatic Signatures

External and Internal causes of Climate Change, Feedback processes, Global and regional trends in greenhouse gas emissions, Milutin Milankovitch and Milankovitch Cycles; James E. Lovelock and Gaia Hypothesis; Global and Regional climate projections and associated uncertainty, Paleoclimatic signatures of climate change (glacial cycles, ocean sediments, corals, tree rings, speleothems)

Unit IV Impact of Climate Change

Climate Change since the nineteenth century, Eustatic Changes, Role of oceans and forests as carbon sinks. Effects on organisms including humans; effects on ecosystems and productivity; species responses in terms of distribution ranges, adaptation; spread of diseases; Extinction risk for temperature-sensitive species; UV effects, Global warming and its manifestation on Climate Change, Influence of Extra-terrestrial forces on Climate Change including variation in atmospheric soil and ocean temperature.

Suggested Readings:

- Ruddiman W F, Earth's Climate past and Future, W.H. Freeman, 2007
- Bengtsson F. O., Geosphere Biosphere Interaction and Climate, Cambridge University Press, 2001
- Berdowski J., Guichert R. and Heil B., The Climate System, A.A. Blakema Publisher, 2000
- Hardy J. T., Climate Change: Causes, effects and solutions, John Wiley and Sons, 2003
- Barry, R. G., 2003. Atmosphere, weather and climate. Routledge Press, UK Ellis,
- Firor, J., & Jacobsen, J. E. 2002. The crowded greenhouse: population, climate change and creating a sustainable world. Yale University Press.
- Graham, S. 2000. https://earthobservatory.nasa.gov/Features/Milankovitch/ Harvey, D. 2000. Climate and Global Climate Change, Prentice Hall.
- Huybers, P. and Curry, W. 2006. Links between annual, Milankovitch and continuum temperature variability. Nature, 441: 329
- Mukherjee, S., Extra-terrestrial Influence on Climate Change, Springer, 2013.
- Foken, T.; Micrometeorology. Springer-Verlag, Berlin, Heidelberg, 2008

CORE PRACTICAL PAPER

The lab work component has been covered in first three semesters and will be called as Practical I, Practical II and Practical III, completed in I, II and III semesters respectively. A set of experiments specially designed for tools and techniques for environmental studies and Remote Sensing and GIS software for hydrological, glacial and climate change studies by faculty members of the department and carried out in laboratory.

ENVS-PG-P109: Practical I

- Practical based on plant characterises and diversity
  a. Determination of density, frequency, abundance, and dominance of plant species using quadrat method.
  b. Calculate photosynthetic efficiency
  c. Estimation of chlorophyll content different plants.
  d. Analysis of carbon content in different part of plants
- Practical based on physico-chemical properties of water
  a. Comparison of different physical characteristics of spring and river water.
  b. Comparison of hardness of spring and river water
  c. Comparison of ion present in spring and river water
  d. Estimation of total suspended solids in river water
- Practical based on Soil texture, bulk density, porosity and water retention
  a. Measurement of physical parameters of Soil.
  b. Identification of soil texture - clay, sand, and loamy.
  c. Calculate bulk density and porosity of a soil sample.
  d. Calculation of permeability of soil.
- Identification of common minerals & major rock types

a. Study of physical properties (color, hardness, streak, clevage, habit, specific gravity etc.) of selected samples.
b. Study and identification of common rock forming minerals (quartz, feldspars, micas, garnets, kyanite, sillimanite, andalusite etc.)
c. Study and identification of basic rock types that includes study of representatives of igneous, sedimentary, and metamorphic rocks.

ENVS-PG-P209: Practical II

- Preparation of Hazard Zonation map by using Remote Sensing and GIS
  a. Seismic micro zonation maps
  b. Landslide hazard zonation mapping using Landslide Hazard Evaluation Factor rating scheme.
  c. Glacial lake outburst flood hazard zonation mapping based on open source data.
- Practical based on Glacier Processes by using Remote Sensing and GIS
  a. Delineation of snow and glaciers on satellite images
  b. Morphometric analysis of glaciers
  c. Estimation of glacier mass balance AAR method
  d. Estimation of glacier mass balance Geodetic Method
- Practical based on Solar radiation and heat budget
  a. Calculation of solar radiation received of ROI
  b. Hear budget preparation of different climatic zones.
- Evaluation and estimation of hydrologic parameters; catchment delineation; water balance and groundwater resources estimation
  a. Morphometric analysis of watershed
  b. Identification of water divide, rain shadow zones, stream numbering, etc.
  c. Preparation of LULC maps

ENVS-PG-P309: Practical III

- Practical based on measurement and characterization of air pollutants
  a. Mass size distribution of ambient aerosols
  b. Preparation of wind rose
  c. Field measurement of Black carbon, CH_4, CO and CO_2
  d. Estimation of different atmospheric pollutant by Remote sensing methods
- Practical based on measurement of water quality
  a. Determination of Heavy Metal analysis in drinking water
  b. Determination of Dissolved Oxygen (DO) of wastewater.
  c. Determination of Biological Oxygen Demand (BOD) of wastewater.
  d. Determination of Chemical Oxygen Demand (COD) of wastewater.
- Practical based on measurement and characterization soil pollutants
  a. Estimation of heavy metal contamination in soil.
  b. Estimation of pesticides contamination in soil.
  c. Serial dilution technique for soil sampling.
  d. Estimation of C-N Content in Soil

- Practical based on measurement Noise level and calculation of different Indices
  a. Measurement of noise level in different zones as specified by CPCB.
  b. Calculation of sound intensity and sound pressure level
  c. Calculation of Noise Indices (L_{90}, L_{50}, L_{10}, Leq, LDN, and SEL) in different zones
  d. Estimation of Noise climate and Noise Dose

CORE FIELD TRAINING

ENVS-PG-F401: Field Training

To strengthen the field work component and to have a wider exposure of the field conditions, students will undergo extensive field work which will help them in developing the understanding of different aspects of environmental sciences. Field work will broadly cover Hydrology, Geomorphology Mapping, Glacier Processes, Alpine Biodiversity and Climate Change and Pollution Studies. Field work is completed in I, II, and III semester and each student shall submit a field work report for evaluation which will be evaluated in 4th semester.

DISSERTATION

ENVS-PG-D402: Dissertation

Students will work for M. Sc. Dissertation under the supervision of a formally assigned supervisor in the Department. Assigning a supervisor will be based on academic interest shown by the student in research specialization of the concerned faculty member followed by the consent given by the faculty member to supervise the dissertation work of that particular student. Student shall complete the process of academic interaction to obtain teachers consent to supervise his/her dissertation work by the end of second semester. Student may carry out his/her dissertation work at any other university, research institute, research laboratory and research organisation provided any faculty/scientist there agree for joint supervision of dissertation work. The work on research work will start after the 3rd semester under the supervision of concerned faculty members and will be completed by end of 4th semester with writing and submission of dissertation. Students will have to present their work and defend it in an open viva- voce.