FYUGP IN OCEAN SCIENCES (MAJOR WITH MINOR PATHWAY)

Major Oceanography with two pathway (Pathway-1: Marine Chemistry, Pathway-2: Marine Biology

SEMESTER I

Course	Course Code	Course Title	Credits
Major- Discipline Specific Core (DSC)			
	OS-POC-101	Introductory Physics	4
		Introductory Mathematics (Mathematics-1)	4
Pathyway:1 Minor -**Discipline Specific Core in Marine Chemistry**			
	OS-MMC-101	Fundamentals of Chemistry for Ocean Science	4
	OS-MMC-102	Co-ordination Chemistry and Environmental Analytical techniques	4
Pathyway:2 Minor -**Discipline Specific Core in Marine Biology**			
	OS-BO-101	Introduction to Biological Oceanography	4
	OS-BO-102	Marine Biotic Environment	4
MDC			
	OS-MDC- 101	Global and Indian Maritime History + UNCLOS	3
AEC			
	AEC-1	English-1	3
	AEC-2	Malayalam-1 / Hindi-1	3
			21

SEMESTER II

Course	Course Code	Course Title	Credits
Major- Discipline Specific Core (DSC)			
	OS-POC-201	Mechanics and Properties of Matter	4
		Mathematics-2	4
Pathyway:1 Minor -**Discipline Specific Core in Marine Chemistry**			
	OS-MMC-201	Fundamentals of Marine Chemistry	4
	OS-MMC-202	Applied Chemical Oceanography	4
Pathyway:2 Minor -**Discipline Specific Core in Marine Biology**			

	OS-BO-201	Primary Productivity and Pelagic Ecology	4
	OS-BO-202	Benthic Ecology and Coastal Ecosystems	4
MDC			
	OS-MDC-201	Environmental and Biodiversity Laws and Sustainable Development Goals	3
AEC	AEC-3	English-2	3
	AEC-4	Malayalam-2 / Hindi-2	3
			21

SEMESTER III

Course	Course Code	Course Title	Credits
Major- Discipline Specific Core (DSC)			
	OS-POC-301	Thermodynamics	4
	OS-POC-302	Introduction to Oceanography	4
Major- Discipline Specific Elective (DSE)			
	OS-POE-301	Introduction to Atmospheric Physics	3
	OS-POE-302	Vector Calculus, Differential Equations and Analytic Geometry	3
Pathyway:1 Minor -**Discipline Specific Core in Marine Chemistry**			
	OS-MMC-301	Marine Chemistry	4
Pathyway:2 Minor -**Discipline Specific Core in Marine Biology**			
	IMB3-MB-DSC3-101	Marine Biodiversity I: Invertebrates and Reef Ecology	4
MDC			
	OS-MDC-301	Descriptive Statistics	3
VAC			
	OS-VAC-301	Hydro-chemical Assessment Techniques	3
			23

SEMESTER IV

Course	Course Code	Course Title	Credits
Major- Discipline Specific Core (DSC)			

	OS-POC-401	Geophysical Fluid Dynamics	4
Major- Discipline Specific Elective (DSE)			
	OS-POE-401	Remote sensing of Oceans	4
	OS-POE-402	Fourier Series, Partial Differential Equations, Numerical Analysis and Abstract Algebra	4
Pathyway:1 Minor -**Discipline Specific Core in Marine Chemistry (any one)**			
	OS-MMC-401	Biogeochemistry	4
	OS-MMC-402	Marine Pollution	4
Pathyway:2 Minor -**Discipline Specific Core in Marine Biology (any one)**			
	IMB4-MB-DSC6-101	Marine Biodiversity II: Vertebrates and Marine Mammals	4
	IMB4-MB-DSC7-102	Marine Botany and Algal Diversity	4
SEC **(any one)**			
	OS-SEC-401	Introduction to Python Programming	3
	OS-SEC-402	Sampling Techniques in Marine Chemistry	3
VAC			
	OS-VAC-401	Marine Natural Products Extraction Techniques	3
			24

Summer Interim Dissertation	2

SEMESTER V

Course	Course Code	Course Title	Credits
Major- Discipline Specific Core (DSC)			
	OS-POC-501	Descriptive Physical Oceanography	4
	OS-POC-502	Dynamical Oceanography	4
	OS-POC-503	Waves and Tides	4
Major- Discipline Specific Elective (DSE) (any one)			
	OS-POE-501	General Meteorology	4
	OS-POE-502	Essentials of Biological Oceanography	4

Pathyway:1 Minor -**Discipline Specific Core in Marine Chemistry (any one)**			
	OS-MMC-501	Marine Geochemistry	4
	OS-MMC-502	Chemistry of Marine Natural Products	4
Pathyway:2 Minor -**Discipline Specific Core in Marine Biology (any one)**			
	IMB5-MB-DSC10-201	Marine Ecological Dynamics and Marine Environment Assessment	4
	IMB5-MB-DSC13-320	Genomics, Proteomics and Molecular Genetics	4
SEC			
	OS-SEC-501	Computer Applications in Oceanography	3
			25

SEMESTER VI

Course	Course Code	Course Title	Credits
Major- Discipline Specific Core (DSC)			
	OS-POC-601	Air Sea Interaction	4
	OS-POC-602	Coastal and Estuarine Processes	4
	OS-POC-603	Oceanographic Instruments	4
Major- Discipline Specific Elective (DSE) (any one)			
	OS-POE-601	Marine Geology	4
	OS-POE-602	Marine Biogeochemical Processes	4
		MOOC-1	4
Pathyway:1 Minor -**Discipline Specific Core in Marine Chemistry**			
	OS-MMC-601	Instrumental Methods in Marine Chemistry	4
Pathyway:2 Minor -**Discipline Specific Core in Marine Biology**			
	IMB6-MB-DSC14-310	Deep Sea -Ecology and Biodiversity	4
SEC			
	OS -SEC-601	Oceanographic/Meteorological data analysis	3
VAC (Any One)			
	OS-VAC-601	Sedimentary Geochemistry Diagnostics Techniques	3
	OS-VAC-602	Fundamentals of R programming	3
			25

SEMESTER VII

Course	Course Code	Course Title	Credits
Major- Discipline Specific Core (DSC)			
	OS-POC-701	Ocean Modelling	4
	OS-POC-702	Ocean State Forecasting	4
Major- Discipline Specific Elective (DSE) (any two)			
	OS-POE-701	Oceans and climate	4
	OS-POE-702	Coastal Hazards and Management	4
		MOOC-2	4
Pathyway:1 Minor -**Discipline Specific Core in Marine Chemistry**			
	OS-MMC-701	Atmospheric Chemistry	3
	OS-MMC-702	Environmental Impact Assessment	3
Pathyway:2 Minor -**Discipline Specific Core in Marine Biology**			
	OS-MMB-701	Fisheries Oceanography	3
	OS-MMB-702	Coral Reef Ecosystem	3
			25

SEMESTER VIII

Course	Course Code	Course Title	Credits
Major- Discipline Specific Core (DSC)			
	OS-POC-801	Coastal Ocean modelling	4
	OS-POC-802	Coastal Engineering	4
		Final Dissertation	12 /8
			20/ 16

Course Components	Number of Courses										Total
	Semester 1	Semester 2	Semester 3	Semester 4		Semester 5	Semester 6	Total	Semester 7	Semester 8	
Major (DSC)	1	1	2	1		3	3	**11**	2	2	**15**
Major (DSE)			2	2		1	1	**6**	2		**8**
Minor (DSC)	2	2	1	2		2	1	**10**	2		**12**
Research (DSE)									1		
MDC (3 Credit /Course)	1	1	1 (IKS)					**3**			**3**
AEC (3 Credit /Course)	Eng Hindi /Mal	Eng Hindi /Mal						**4**			**4**
SEC (3 Credit /Course)				1		1	1	**3**			**3**
VAC (3 Credit /Course			1	1			1	**3**			**3**
Project/ Dissertation										12-Aug	**1**
Total Courses	**6**	**6**	**7**	**7**		**7**	**7**	**33**	**7**	**2+1**	**51**
Total Credits	**21**	**21**	**23**	**22**	**2***	**25**	**25**	**139**	**25**	**20**	**184**
Total Hours/ Week								**Exit Option**			

Semester: I

Major: DSC

OS-POC-101 Introductory Physics

Module: I

Units and Dimensions

Development of physics and the birth of new scientific concepts with reference to scientific contributions of Galileo – perspectives on universe, Newton- deterministic universe.

Fundamental and derived quantities. Units and dimensions, dimensional analysis, order of magnitude, significant figures, errors.

Module: II

Motion

Velocity, acceleration, momentum, Idea of inertia, force - laws of motion. Newton's law of gravitation, acceleration due to gravity, mass and weight, apparent weight, weightlessness. Rotational motion, Moment of inertia, torque, centripetal and centrifugal acceleration examples- banking of curves, centrifugal pump, roller coasters.

Module: III

Light

Reflection, refraction, diffraction, interference, scattering (elementary ideas only) – examples from daily life – apparent depth, blue colour of sky, twinkling of stars. Total internal reflection, mirage, sparkling of diamond, primary and secondary rainbow – optical fibres. Concave and convex mirrors, lenses – focal length, power of a lens, refractive index, prism, dispersion. Human eye, defects of the eye – myopia, hypermetropia, presbyopia and astigmatism and their correction by lens.

Module: IV

Electricity

Voltage and current, ohms law. Electric energy, electric power, calculation of energy - requirement of electric appliances – transformer, generator, hydroelectric power generation – wind power – solar power – nuclear power.

Module: V

Matter and Energy

Different phases of matter, fluids - surface tension, viscosity- capillary rise, Bernoulli's theorem and applications -Heat energy, temperature, different temperature scales – degree Celsius, Fahrenheit and Kelvin. Waves – transverse and longitudinal waves, sound waves, Doppler Effect. Electromagnetic waves.

Reference

1. Fundamentals of Physics with Applications by Arthur Beiser

2. Conceptual Physics by Paul G Hewitt

Pathway: 1 Minor – Discipline Specific Core in Marine Chemistry OS-MMC-101 Fundamentals of Chemistry for Ocean Science

Module: I – Atomic Structure, Periodicity and Chemical Bonding (12 Hrs)

Fundamentals of Matter

- Matter and its classification
- Elements, compounds and mixtures
- Physical and chemical properties
- SI units and scientific notation
- Significant figures
- Basic chemical calculations

Atomic Structure

- Fundamental particles
- Atomic number and mass number
- Isotopes and isobars
- Electronic configuration
- Orbitals and quantum numbers – elementary concepts

Periodic Table

- Modern periodic law
- Periodic trends

- Atomic radius
- Ionization energy
- Electron affinity
- Electronegativity
- Metallic and non-metallic character

Chemical Bonding

- Ionic, covalent and coordinate bonds
- Lewis structures
- Octet rule
- Electronegativity and bond polarity
- Hydrogen bonding
- van der Waals interactions
- Molecular geometry – basic VSEPR concept

Module: II – Stoichiometry, States of Matter and Solutions (12 Hrs)

Mole Concept

- Atomic and molecular masses
- Mole and Avogadro constant
- Molar mass
- Empirical and molecular formulae
- Percentage composition

Chemical Equations and Stoichiometry

- Writing and balancing chemical equations
- Stoichiometric calculations
- Limiting reagent
- Percentage yield

Gaseous State

- Gas laws
- Boyle's law
- Charles' law

- Avogadro's law
- Ideal gas equation
- Partial pressure
- Solubility of gases in water

Liquid State

- Properties of liquids
- Vapour pressure
- Surface tension
- Viscosity
- Hydrogen bonding

Solutions

- Solute and solvent
- Molarity
- Molality
- Mole fraction
- Percentage concentration
- Dilution
- Electrolytes and non-electrolytes

Module: III – Water Chemistry, Acids, Bases and Carbonate System (14 Hrs)

Chemistry of Water

- Structure and properties of water
- Polarity and hydrogen bonding
- Water as a universal solvent
- Hydration of ions
- Ionic strength – elementary concept

Acids and Bases

- Arrhenius concept
- Brønsted–Lowry concept
- Conjugate acid–base pairs

- Strong and weak acids and bases
- Ionization of water
- pH and pOH
- Acid and base strength

Buffer Systems

- Buffer solutions
- Buffer action
- Henderson–Hasselbalch equation
- Buffering capacity – introductory concept
- Importance of buffering in natural waters

Marine Carbonate Chemistry

- Carbon dioxide in water
- Carbonic acid
- Bicarbonate and carbonate ions
- Carbonate equilibria
- Alkalinity – introductory concept
- Calcium carbonate precipitation and dissolution
- Carbonate saturation – introductory concept

Ocean Acidification

- Increasing atmospheric CO_2
- Dissolution of CO_2 in seawater
- Changes in seawater pH
- Changes in carbonate ion availability
- Consequences for calcifying organisms
- Implications for coral reefs and marine ecosystems

Module: IV – Chemical Equilibrium, Thermochemistry and Redox Chemistry (12 Hrs)

Chemical Equilibrium

- Reversible reactions
- Dynamic equilibrium

- Equilibrium constant
- Le Chatelier's principle
- Factors affecting equilibrium

Solubility Equilibrium

- Solubility
- Solubility product
- Common ion effect
- Precipitation and dissolution
- Introduction to mineral saturation

Thermochemistry

- System and surroundings
- Heat and work
- Exothermic and endothermic processes
- Enthalpy
- Specific heat capacity
- Hess's law – elementary treatment

Redox Chemistry

- Oxidation and reduction
- Oxidizing and reducing agents
- Oxidation number
- Balancing simple redox reactions
- Introduction to electrochemical processes

Redox Processes in Marine Systems

- Dissolved oxygen
- Oxic and anoxic conditions
- Oxidation of organic matter
- Reduction processes in sediments
- Iron and manganese cycling
- Sulphate reduction

- Hydrogen sulphide formation

Module:V – Basic Organic Chemistry and Marine Chemical Processes (10 Hrs)

Introduction to Organic Chemistry

- Carbon and its unique properties
- Catenation
- Saturated and unsaturated compounds
- Structural formulae

Hydrocarbons

- Alkanes
- Alkenes
- Alkynes
- Aromatic compounds – introductory concept

Functional Groups

- Alcohols
- Aldehydes
- Ketones
- Carboxylic acids
- Esters
- Amines
- Amides

Organic Matter in the Ocean

- Carbohydrates
- Amino acids and proteins
- Lipids
- Natural organic matter
- Dissolved organic carbon
- Particulate organic matter

Organic Contaminants

- Petroleum hydrocarbons

- Pesticides
- Persistent organic pollutants
- Plastic-associated chemicals
- Introduction to microplastics and nanoplastics

Suggested Practicals:

1. Laboratory safety and basic laboratory practices.
2. Measurement of mass and volume; use of volumetric glassware.
3. Preparation of standard solutions.
4. Preparation of solutions of known molarity.
5. Dilution of standard solutions.
6. Determination of pH of different water samples.
7. Comparison of pH of freshwater, estuarine water and seawater.
8. Acid–base titration using a suitable indicator.
9. Determination of hardness of water by EDTA titration – introductory experiment.

Suggested Textbooks

1. Atkins, P. & Jones, L. – Chemical Principles W.H. Freeman/Macmillan.
2. Brown, T.L., LeMay, H.E., Bursten, B.E. et al. – Chemistry: The Central Science Pearson.
3. Petrucci, R.H., Herring, F.G., Madura, J.D. & Bissonnette, C. – General Chemistry: Principles and Modern Applications. Pearson.
4. Libes, S.M. – An Introduction to Marine Biogeochemistry. Wiley.
5. Pilson, M.E.Q. – An Introduction to the Chemistry of the Sea. Cambridge University Press.
6. Millero, F.J. – Chemical Oceanography. CRC Press.
7. Emerson, S. & Hedges, J. – Chemical Oceanography and the Marine Carbon Cycle Cambridge University Press.
8. Stumm, W. & Morgan, J.J. – Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters. Wiley.
9. Morel, F.M.M. & Hering, J.G. – Principles and Applications of Aquatic Chemistry Wiley.

Paper-II- Coordination Chemistry and Environmental Analytical Techniques- (Credits 4)

Module: I – Fundamentals of Coordination Chemistry (15 Hrs)

Introduction to Coordination Chemistry

- Coordination compounds – basic concept
- Central metal atom/ion
- Ligands and coordination number
- Coordination sphere
- Simple examples of coordination compounds
- Importance of coordination chemistry in environmental and marine chemistry

Types of Ligands

- Monodentate ligands
- Bidentate ligands
- Polydentate ligands
- Chelating ligands
- Ambidentate ligands
- Examples of common ligands

Nomenclature of Coordination Compounds

- Basic rules of nomenclature
- Naming ligands
- Naming metal ions
- Oxidation state
- Coordination number

- Simple examples

Isomerism in Coordination Compounds

- Structural isomerism – basic concept
- Geometrical isomerism
- Optical isomerism
- Simple examples

Coordination Number and Geometry

- Coordination number 2, 4 and 6
- Linear, tetrahedral, square planar and octahedral geometries
- Factors affecting geometry

Module: II – Bonding, Stability and Reactions of Coordination Compounds (15 Hrs)

Theories of Coordination Compounds

- Werner's coordination theory
- Basic concepts of valence bond theory
- Hybridisation and geometry
- Elementary introduction to crystal field theory

Crystal Field Splitting

- Octahedral complexes
- Tetrahedral complexes
- Square planar complexes
- High-spin and low-spin complexes – basic concept
- Colour and magnetic properties – qualitative treatment

Stability of Coordination Compounds

- Stability concept
- Formation/stability constants – basic idea
- Factors affecting stability
- Chelate effect

Reactions of Coordination Compounds

- Ligand substitution – basic concept
- Complex formation and dissociation
- Acid–base effects
- Influence of pH on metal complexation

Coordination Chemistry in Aquatic Systems

- Complexation of metal ions in natural waters
- Organic ligands in seawater
- Metal speciation – elementary concept
- Influence of complexation on metal transport and bioavailability
- Examples: Fe, Cu, Zn and other trace metals

Module: III – Fundamentals of Environmental Analytical Chemistry (15 Hrs)

Introduction to Analytical Chemistry

- Qualitative and quantitative analysis
- Classical and instrumental methods
- Environmental and marine analytical chemistry
- Importance of chemical measurements in pollution monitoring

Environmental Sampling

- Principles of representative sampling
- Water sampling
- Seawater and estuarine water sampling
- Sediment sampling – basic concept
- Sample preservation
- Contamination and precautions

Preparation of Environmental Samples

- Filtration
- Digestion – basic concept
- Dilution
- Extraction – elementary concept

- Concentration of analytes
- Importance of clean laboratory practices

Errors and Quality of Analytical Measurements

- Accuracy and precision
- Random and systematic errors
- Significant figures
- Detection limit – basic concept
- Calibration
- Blanks and standards
- Replicate analysis
- Quality assurance and quality control

Basic Quantitative Analytical Methods

- Concentration units
- Molarity
- Normality – elementary concept
- Percentage concentration
- ppm and ppb
- Preparation of standard solutions – Primary and Secondary standards.

Module: IV – Classical and Instrumental Environmental Analysis (15 Hrs)

Volumetric Analysis

- Principle of titrimetric analysis
- Acid–base titrations
- Redox titrations
- Complexometric titrations
- Precipitation titrations
- Environmental applications

Gravimetric Analysis

- Basic principle

- Precipitation and weighing
- Sources of error
- Environmental applications

Colorimetry and Spectrophotometry

- Interaction of light with matter
- Absorption of radiation
- Beer–Lambert law
- Colorimeter
- UV–Visible spectrophotometer
- Calibration curve
- Determination of analyte concentration
- Applications in water and marine environmental analysis

Atomic Absorption Spectroscopy – Basic Introduction

- Principle
- Instrument components
- Sample introduction
- Applications for metal analysis
- Environmental applications

Chromatographic Techniques – Basic Introduction

- Principle of chromatography
- Stationary and mobile phases
- Paper and thin-layer chromatography
- Gas chromatography – basic concept
- Liquid chromatography – basic concept
- Applications in environmental pollutant analysis

Overview of Modern Environmental Analytical Techniques

- ICP-OES/ICP-MS – basic concept
- GC-MS – basic concept
- LC-MS – basic concept

- FTIR – basic concept
- Raman spectroscopy – basic concept
- Selection of techniques for environmental pollutants

Suggested Practicals:

1. Preparation of standard solutions- Primary and Secondary standards of known normality and molarity.

2. Determination of pH of water samples.

3. Determination of alkalinity of water.

4. Determination of hardness by EDTA titration.

5. Determination of chloride by titration.

6. Demonstration of complex formation.

7. Preparation of calibration curve using spectrophotometric data.

8. Determination of an analyte using UV–Visible spectrophotometry- Demonstration.

9. Demonstration of AAS/ICP-MS for trace-metal analysis.

10. Demonstration of chromatographic separation – Column Chromatography and Thin Layer Chromatography only.

Suggested Books

1. J. E. Huheey, E. A. Keiter & R. L. Keiter, *Inorganic Chemistry: Principles of Structure and Reactivity*.
2. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann, *Advanced Inorganic Chemistry*.
3. R. G. Wilkins, *Kinetics and Mechanism of Reactions of Transition Metal Complexes*.
4. D. F. Shriver & P. W. Atkins, *Inorganic Chemistry*.
5. D. A. Skoog, D. M. West, F. J. Holler & S. R. Crouch, *Fundamentals of Analytical Chemistry*.
6. D. A. Skoog, F. J. Holler & S. R. Crouch, *Principles of Instrumental Analysis*.
7. D. C. Harris, *Quantitative Chemical Analysis*.
8. Vogel, *A Textbook of Quantitative Chemical Analysis*.
9. F. J. Millero, *Chemical Oceanography*.
10. J. P. Riley & R. Chester, *Introduction to Marine Chemistry*.
11. S. E. Manahan, *Environmental Chemistry*.

Pathway: II Minor – Discipline Specific Core in Marine Biology

Paper 1- Introduction to Biological Oceanography (Credits - 4)

Module I:

Scope and importance of Biological Oceanography, Historical development of Biological Oceanography, Interdisciplinary nature of ocean sciences, Ocean basins and major marine environments, Classification of marine habitats, Classification of marine organisms, Basic ecological terms and concepts

Module II:

Physical Characteristics of the Marine Environment - Origin and distribution of seawater, Solar radiation and light in the ocean, Temperature distribution, Salinity, Density, Hydrostatic pressure, Ocean stratification, Mixing processes

Module III

Ocean Dynamics and Marine Environment - Surface currents, Waves and tides, Upwelling and downwelling, Thermocline, halocline and pycnocline, Water masses, Physical factors controlling marine productivity

Module IV

Biological Productivity and Marine Ecosystem Processes - Primary productivity, Secondary productivity, Marine food chains and food webs, Biogeochemical cycles, Carbon cycle, Nitrogen cycle, Role of microorganisms in nutrient cycling

Module V

Biological Oceanography in Practice - Introduction to ocean observation systems, Marine sampling methods, Oceanographic cruises, Basic oceanographic instruments. Applications of Biological Oceanography in: Fisheries, Environmental monitoring, Climate studies, Blue Economy, Ocean advisory services.

Reference List

- **Lalli, C. M., & Parsons, T. R.** ***Biological Oceanography: An Introduction*****.**
- **Menden-Deuer, S., et al.** ***Biological Oceanography*** **(3rd edition).**
- **Pan, J., & Pratolongo, P. (eds.).** ***Marine Biology: A Functional Approach to the Oceans and their Organisms*****.**
- ***Primary Productivity and Biogeochemical Cycles in the Sea*****.**

Paper II- Marine Biotic Environment (Credits - 4)

Module I

Marine Microorganisms - Marine microbial diversity (Cyanobacteria, Marine bacteria, Marine fungi, Marine viruses), Ecological importance of marine microorganisms, Microbial loop

Module II

Marine Plankton - Introduction to plankton, Classification of plankton, Phytoplankton (Major groups, Ecological significance), Zooplankton, Holoplankton, Meroplankton, Plankton adaptations, Role of plankton in marine food webs

Module III

Marine Macrophytes - Marine macroalgae (Seaweeds), Kelp forests, Seagrasses, Mangrove ecosystems, Ecological and economic importance, Blue carbon ecosystems

Module IV

Marine Invertebrates - General characteristics and ecological importance (Porifera, Cnidaria, Annelida, Mollusca, Arthropoda, Echinodermata), Adaptations to marine habitats

Module V

Marine Vertebrates and Biodiversity – Chordata, Fishes, Marine reptiles, Marine birds, Marine mammals. Marine biodiversity, Species interactions, Marine food webs, Threats to marine biodiversity, Introduction to marine conservation

Reference List

1. Kirchman, D. L. *Microbial Ecology of the Oceans*.
2. Morrissey, J. F., Sumich, J. L., & Pinkard-Meier, D. R. *Introduction to the Biology of Marine Life*.
3. Levinton, J. S. *Marine Biology: Function, Biodiversity, Ecology*.
4. Raymont, J. E. G. *Plankton and Productivity in the Oceans*.
5. Lalli, C. M., & Parsons, T. R. *Biological Oceanography: An Introduction*.

Suggested Practicals:

Practicals I

1. Preparation of standard solutions- Primary and Secondary standards of known normality and molarity.

2. Determination of pH of water samples.

3. Determination of alkalinity of water.

4. Determination of hardness by EDTA titration.

5. Determination of chloride by titration.

6. Preparation of calibration curve using spectrophotometric data.

7. Determination of an analyte using UV–Visible spectrophotometry- Demonstration.

8. Demonstration of chromatographic separation – Column Chromatography and Thin Layer Chromatography only.

Practicals II

1. Field visit to a coastal ecosystem
2. Handling and use of microscopes
3. Sample collection and microscopic observation of marine microorganisms
4. Culture, staining and observation of microorganisms
5. Identification of flora and fauna based on field visit
6. Biodiversity assessment of a coastal ecosystem-Observation of ecological adaptations in marine organisms; preparation of biodiversity records.

MDC – Global and Indian Maritime History and the laws of the seas (Credits – 3)

Unit I: **Global Maritime History**:

Evolution of maritime activities and seafaring: Origins of navigation, boat building and maritime technology; development of early maritime civilizations and seaborne trade. Ancient maritime civilizations and their maritime trade, naval power and overseas interactions. Indian Ocean maritime networks: Maritime trade and cultural exchanges among East Africa, Arabia, Persia, India, Southeast Asia and China; influence of monsoon winds on navigation and trade. Maritime Silk Routes: Development of maritime trade between Asia, Africa and Europe; role of major ports and trading centres. European maritime expansion: Portuguese, Spanish, Dutch, French and British maritime exploration, trade and colonial expansion. Age of Exploration: Major voyages, discovery of sea routes and their impact on global trade and international relations. Colonial maritime powers and naval competition: Establishment of maritime empires, naval bases and strategic control of major sea routes and chokepoints. Industrial Revolution and maritime transformation: Transition from sail to steam, development of modern shipbuilding, navigation technologies, canals and modern shipping. World Wars and maritime power and the strategic importance of oceans during the First and Second World Wars. Emergence of maritime superpowers and changing strategic importance of the oceans. Contemporary global maritime system: Global shipping, ports, maritime trade routes, maritime security, fisheries, marine resources and the changing geopolitical significance of oceans.

Unit II: Indian Maritime History:

Early Indian maritime traditions: Origins of seafaring, navigation, boat building, fishing and coastal trade; development of maritime activities in ancient India. Indus Valley Civilization: Maritime trade and cultural links, major coastal settlements, ports and trade routes. Ancient Indian Ocean networks: Maritime trade and cultural exchanges between India, Arabian nations, Persia, West Asia, East Asia and Southeast Asia; role of monsoon winds in Indian navigation and trade. Mauryan Period: Maritime administration, ports, overseas trade and naval activities;

expansion of Buddhism through maritime routes and its influence across Sri Lanka and Southeast Asia. Pandyan Kingdom: Maritime trade, naval activities and overseas expeditions; commercial and cultural relations with Sri Lanka and Southeast Asia. Chera Kingdom: Maritime trade and activities along the Malabar Coast; relations with the Roman world, Arabia and other Indian Ocean regions; significance of ancient ports and spice trade. Chola Empire: Development of naval power; maritime expeditions and expansion; relations with Sri Lanka and Southeast Asia; Chola influence over maritime trade networks and ports. Gupta Period: Maritime trade, ports and overseas commercial and cultural contacts with Southeast Asia and other regions. Medieval Indian maritime traditions: Role of Arab, Persian and Indian maritime communities; development of coastal ports and trading networks. European maritime powers in India: Portuguese, Dutch, French and British naval presence, trading settlements and maritime strategies; competition for control of Indian Ocean trade routes. Colonial maritime influence: Transformation of Indian ports, shipping, naval infrastructure and maritime trade under European colonial powers. Indian maritime heritage and strategic significance: Historical evolution of India's maritime interests, coastal communities, ports, trade routes and naval traditions in shaping India's contemporary maritime identity and strategic position in the Indian Ocean.

Unit III: India and her Neighbours:

Forms of Government, Executive, Legislature and Judicial System Neighbouring Countries and their relationship with India Indian Ocean Region Indo-Pacific

Areas of Dispute with particular reference to South Asia International and Regional Organisations like the UNO, OPEC, NAM, EU, League of Arab States, WARSAW Pact, NATO, SAARC, BRICS, ASEAN, SAGAR, FOIP and IPOI. China Strategy of 21st Century Maritime Silk Road.

Unit IV: India Foreign Policy and Maritime Diplomacy:

State Sovereignty- Territoriality of National Laws, Codification of maritime zones, United Nations Convention on the Law of the Sea, BBNJ, Port State and Flag states, Organisations: Food and Agricultural Organization, Regional Fishery Management, Regional fishery advisory bodies, Agreement on Sanitary and phytosanitary measures, WTO, dispute settlement, International Tribunal for the Laws of the Seas (ITLOS), Legal and ethical aspects of using Technology (AI, Satellite data, drones, etc)

Reference List:

1. Abulafia, D. The Boundless Sea: A Human History of the Oceans. Oxford University Press, 2019.
2. Chaudhuri, K. N. Trade and Civilisation in the Indian Ocean: An Economic History from the Rise of Islam to 1750. Cambridge University Press, 1985.
3. Sridharan, K. A Maritime History of India.
4. Mookerji, R. K. Indian Shipping: A History of the Sea-Borne Trade and Maritime Activity of the Indians.

5. Ray, H. P. The Winds of Change: Buddhism and the Maritime Links of Early South Asia. Oxford University Press, 1994.
6. Hiranandani, G. H. Transition to Triumph: History of the Indian Navy, 1965–1975.
7. Kaylor, W. R. A World of Nations: The International Order Since 1945.
8. Kaplan, R. D. Monsoon: The Indian Ocean and the Battle for Supremacy in the Twenty-First Century. Random House, 2010.
9. Churchill, R. R. & Lowe, A. V. The Law of the Sea. Manchester University Press.
10. United Nations. United Nations Convention on the Law of the Sea (UNCLOS), 1982.

DIFFERENTIAL AND INTEGRAL CALCULUS

Module: I

Differential Calculus

Rates of change and limits, calculating limits using the limit laws, the precise definition of a limit, one-sided limits and limits at infinity, derivative of a function, differentiation rules, the derivative as a rate of change, derivatives of trigonometric functions, the chain rule and parametric equations, implicit differentiation.

Module: II

Applications of Derivatives

Extreme values of functions, The Mean Value Theorem, Monotonic functions and the

first derivative test.

Module: III

Integral Calculus

A quick review of indefinite integral as anti-derivative, The Definite integral, The fundamental theorem of Calculus.

Module: IV

Application of Integrals

Substitution and area between curves, Volumes by slicing and rotation about an axis (disc method only), Lengths of plane curves, Areas of surfaces of revolution and the theorem of Pappus (excluding theorem of Pappus).

Reference

1. George B. Thomas, Jr: Thomas Calculus Eleventh Edition, Pearson, 2008.
2. Shanti Narayan: Differential Calculus (S Chand)

3. George B. Thomas Jr. and Ross L. Finney: Calculus, LPE, Ninth edition, Pearson Education.
4. Shanti Narayan, P. K. Mittal: Integral Calculus (S. Chand & Company

Semester: II

Major: DSC

OS-POC-201 Mechanics and Properties of Matter

Module: I

Oscillations and Waves

Periodic motion and harmonic motion, harmonic oscillator, simple harmonic motion, energy of a harmonic oscillator, examples of harmonic oscillator – simple pendulum, loaded spring. damping, damped harmonic oscillator, forced oscillator, resonance

Waves- Types of waves, Characteristics of a wave and wave motion, general equation of a plane progressive harmonic wave, particle velocity differential equation of a wave motion, energy density, energy intensity, superposition of waves, beats, transverse waves in stretched strings, modes and longitudinal waves in gas

Module: II

Dynamics of Rigid Bodies

Rigid body Translational and rotational motion - moment of inertia- Radius of gyration-analogous parameters in translational and rotational motion-General theorems of Moment of inertia- Parallel and perpendicular axes theorems - calculation of moment of inertia (uniform rod, hoop or thin circular ring, circular disc, annular disc-solid cylinder, and solid sphere) moment of inertia of flywheel.

Module: III

Gravitation

Newton’s law of gravitation – density of earth- Mass of the earth and the sun — Gravitational Potential and Gravitational Potential energy- velocity of escape from earth- velocity of escape from solar system-equipotential surface.

Module: IV

Elasticity

Basic ideas on elasticity – Young’s modulus, bulk modulus, rigidity modulus, Poisson’s ratio, bending of beams, bending moment, flexural rigidity. Young's modulus – uniform and non-uniform bending, cantilever. I –section girders. Torsional rigidity-twisting couple on a cylindrical rod- Determination of rigidity modulus using Static method- static torsion and Dynamic method- torsion pendulum.

Module: V

Hydrodynamics

Streamline and turbulent flows, coefficient of Viscosity – Determination of viscosity by Poiseuille's equation. Equation of continuity, energy possessed by a liquid, Bernoulli's theorem.

Surface tension, surface energy, molecular explanation of Surface tension, angle of contacts-shapes of drops-capillary rise.

Reference

1. Mechanics - J.C. Upadhayaya, Ramprasad Pub.

2. Mechanics -D.S. Mathur, S. Chand.

3. Advanced course in Practical Physics - D Chattopadhyay, Central Book

4. Properties of Matter and Acoustics - Murugeshan and K. Sivaprasath, S. Chand

Minor: Marine Chemistry

Paper I - Fundamentals of Marine Chemistry - (Credits-4)

Module: I – INTRODUCTION TO MARINE CHEMISTRY (12 Hrs)

- Marine chemistry and chemical oceanography – scope and importance
- Ocean as a chemical system
- Sources of dissolved substances in seawater
  - atmospheric inputs
  - rivers and terrestrial runoff
  - submarine weathering
  - hydrothermal inputs
  - biological processes
- Removal processes
  - precipitation
  - adsorption
  - biological uptake
  - sedimentation
- Residence time – basic concept
- Major and minor constituents of seawater

- Major ions: Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^- and SO_4^{2-}
- Concept of constant proportions
- Conservative and non-conservative constituents
- Concept of chemical budgets in the ocean

Module: II – PHYSICAL AND CHEMICAL PROPERTIES OF SEAWATER (12 Hrs)

- Pure water versus seawater
- Molecular structure and properties of water
- Hydrogen bonding
- Solvent properties of seawater
- Salinity
  - definition
  - practical salinity
  - chlorinity – basic concept
  - methods of salinity determination
- Temperature and its influence on seawater chemistry
- Density of seawater
- Temperature–salinity relationships
- Water masses – chemical perspective
- Conservative properties
- Mixing of different water masses
- Basic concepts of diffusion and mix

Module: III – ACID–BASE AND CARBONATE CHEMISTRY (12 Hrs)

- Acids, bases and pH
- pH of seawater
- Weak acids and bases
- Buffer systems
- Alkalinity – concept and significance
- Carbon dioxide in seawater
- Dissolution of CO_2

- Carbonic acid–bicarbonate–carbonate equilibrium
- Distribution of carbonate species with pH
- Calcium carbonate
- Precipitation and dissolution of $CaCO_3$
- Biological calcification
- Concept of carbonate saturation
- Introduction to ocean acidification
- Importance of carbonate chemistry to coral reefs and marine organisms with carbonate structure.

Module: IV – DISSOLVED GASES AND OXYGEN (12 hrs)

- Gases in seawater
- Solubility of gases
- Factors controlling gas solubility
- Air–sea gas exchange – basic concept
- Dissolved oxygen
- Sources and sinks of oxygen
- Photosynthesis and respiration
- Oxygen distribution in the water column
- Oxygen minimum zones – introductory concept
- Biological oxygen demand – basic concept
- Dissolved oxygen as an indicator of water quality
- Introduction to Apparent Oxygen Utilization (AOU)

Module: V – MARINE NUTRIENTS AND BASIC BIOGEOCHEMISTRY (12 Hrs)

- Essential nutrients in marine systems
- Nitrogen
  - nitrate
  - nitrite
  - ammonium
- Phosphorus

- phosphate
- Silicon
- dissolved silicate
- Distribution of nutrients in the ocean
- Nutrient limitation
- Redfield ratio – basic concept
- Phytoplankton uptake
- Regeneration and remineralization
- Eutrophication
- Nutrient enrichment in coastal waters
- Introduction to marine biogeochemical cycles

Suggested Practicals

1. Collection, preservation and handling of water samples (Estuarine).
2. Measurement of pH of seawater using a pH meter –Onboard
3. Determination of salinity using a refractometer/conductivity-based salinometer – Onboard.
4. Determination of dissolved oxygen by Winkler's iodometric method –Onboard.
5. Estimation of dissolved inorganic phosphate by colorimetry.
6. Estimation of nitrate/nitrite by colorimetric method – demonstration/data interpretation.
7. Determination of dissolved silicate by spectrophotometric method – demonstration.
8. Calculation of seawater density from temperature and salinity data.
9. Calculation of oxygen saturation from temperature and salinity.
10. Interpretation of a simple temperature–salinity–oxygen dataset.

Suggested Textbooks

1. Pilson, M.E.Q. *An Introduction to the Chemistry of the Sea*, 2nd ed., Cambridge University Press.
2. Riley, J.P. & Chester, R. *Introduction to Marine Chemistry*, Academic Press.
3. The Open University. *Seawater: Its Composition, Properties and Behaviour*, Pergamon.

4. Libes, S.M. *An Introduction to Marine Biogeochemistry*, 2nd ed., Wiley.
5. Millero, F.J. *Chemical Oceanography*, CRC Press.

Paper II - APPLIED CHEMICAL OCEANOGRAPHY - (Credits-4)

Module: I – CHEMICAL EQUILIBRIA AND MARINE CARBON SYSTEM (12 Hrs)

- Review of seawater composition
- Chemical equilibria in seawater
- Activity versus concentration – introductory concept
- Ionic strength
- Acid–base equilibria
- Carbonate system
- CO_2–HCO_3^-–CO_3^{2-} equilibrium
- Total dissolved inorganic carbon
- Total alkalinity
- Carbonate saturation state
- Calcite and aragonite
- Carbonate compensation – basic concept
- Ocean acidification
- Anthropogenic CO_2 and marine carbon chemistry
- Introduction to ocean carbon sequestration
- Ocean as global carbon sink.
- Blue Carbon Ecosystems- Introductory concepts.

Module: II – MARINE BIOGEOCHEMICAL CYCLES (12 Hrs)

Carbon Cycle

- Sources and sinks of marine carbon
- Dissolved inorganic carbon
- Dissolved organic carbon
- Particulate organic carbon

- Biological carbon pump
- Microbial carbon pump
- Carbon export and sequestration
- Blue carbon – introductory concept

Nitrogen Cycle

- Nitrogen fixation
- Ammonification
- Nitrification
- Denitrification
- Anammox
- Nitrogen limitation

Phosphorus Cycle

- Dissolved phosphate
- Organic phosphorus
- Regeneration
- Sedimentary phosphorus

Silicon Cycle

- Dissolved silicate
- Diatom uptake
- Biogenic silica
- Silica dissolution

Module: III – REDOX CHEMISTRY, TRACE ELEMENTS AND MARINE METALS (12 Hrs)

- Oxidation–reduction reactions in marine environments
- Redox potential – basic concept
- Oxygenated, suboxic and anoxic environments
- Redox zonation
- Iron and manganese cycling
- Iron as a micronutrient
- Trace metals in seawater

- Fe
- Mn
- Cu
- Zn
- Ni
- Co

- Essential versus toxic elements
- Chemical speciation – basic concept
- Complexation and organic ligands
- Bioavailability
- Trace-metal sources and sinks
- Atmospheric and riverine inputs
- Hydrothermal sources
- Biological uptake
- Scavenging and particle association
- Introduction to contamination by toxic metals

Module: IV – MARINE SEDIMENT GEOCHEMISTRY AND ORGANIC MATTER (12 Hrs)

- Marine sediments as chemical reactors
- Sediment–water interface
- Physical and chemical processes in sediments
- Organic matter deposition
- Degradation and remineralization
- Early diagenesis – basic concept
- Pore water chemistry
- Oxygen consumption in sediments
- Sulphate reduction
- Methanogenesis
- Methane oxidation

- Iron and manganese reduction
- Nutrient regeneration from sediments
- Role of sediments in coastal biogeochemical cycles

Module: V – CHEMICAL OCEANOGRAPHIC OBSERVATIONS AND ANALYTICAL APPROACHES (12 Hrs)

- Marine chemical sampling strategies
- Water-column sampling
- Surface versus depth sampling
- CTD–Niskin sampling – chemical perspective
- Filtration and sample preservation
- Accuracy, precision and detection limits
- Calibration and standards
- Colorimetry and spectrophotometry
- Flame photometry – basic principle
- Atomic Absorption Spectrometry – principle and applications in ocean monitoring.
- ICP-OES/ICP-MS – introductory concepts and applications in ocean monitoring.
- GC-MS and LC-MS – applications in marine environmental chemistry
- FTIR/Raman spectroscopy – introduction to microplastics identification
- Quality assurance and quality control in environmental monitoring.
- Basic statistical treatment of marine chemical data

Suggested Practicals.

1. Determination of dissolved oxygen and calculation of oxygen saturation.
2. Construction and interpretation of calibration curves.
3. Determination of carbonate/bicarbonate relationships from given seawater data.
4. Calculation of carbonate saturation state using supplied pH, alkalinity and DIC data.
5. Calculation of Apparent Oxygen Utilization (AOU).
6. Calculation of nutrient ratios and interpretation using Redfield stoichiometry.
7. Interpretation of vertical profiles of temperature, salinity, oxygen and nutrients.
8. Field visit to a nearby estuary and collection and analysis of pH, salinity, DO, alkalinity, nutrients.

9. Analysis of a simple trace-metal dataset.
10. Demonstration/data interpretation of AAS or ICP-MS.

Pathway: II Minor – Discipline Specific Core in Marine Biology

Paper 1 Primary Productivity and Pelagic Ecology (Credits - 4)

Module I

Phytoplankton and Marine Primary Production - Introduction to marine primary productivity, Phytoplankton diversity and ecological significance, Photosynthesis in marine environments, Photosynthetic pigments, Chlorophyll pigments, Accessory pigments, Light and photosynthesis, Photosynthetically Active Radiation (PAR)

Module II

Factors Controlling Marine Productivity - Nutrient cycling, Macronutrients and micronutrients, Nutrient limitation, Effect of nutrients on phytoplankton growth, Temperature, Salinity, Light availability, Water column stability, Mixing and stratification, Upwelling and nutrient enrichment, Physical controls of primary production

Module III

Marine Productivity and Oceanic Ecosystems - Gross Primary Productivity (GPP), Net Primary Productivity (NPP), Community Productivity, Phytoplankton biomass, Global patterns of ocean productivity, Coastal vs open ocean productivity, Seasonal productivity, Ocean productivity and fisheries

Module IV

Zooplankton Ecology and Nekton - Zooplankton diversity, Holoplankton and meroplankton, Zoogeography of holoplankton, Vertical distribution, Diel Vertical Migration (DVM), Grazing ecology, Predator-prey interactions, Nekton and trophic dynamics, Role of zooplankton in secondary production

Module V

Benthic Primary Productivity and Pelagic–Benthic Coupling - Benthic primary productivity, Microphytobenthos, Seagrasses, Macroalgae, Seagrasses, Pelagic-benthic coupling, Carbon flux, Biological pump, Ocean productivity under climate change, Applications in fisheries and ecosystem management

Reference List

- Falkowski, P. G., & Raven, J. A. *Aquatic Photosynthesis*.
- Platt, T., & Harrison, W. G. *Primary Productivity and Biogeochemical Cycles in the Sea*.

- Sverdrup, H. U., Johnson, M. W., & Fleming, R. H. *The Oceans: Their Physics, Chemistry, and General Biology*.
- Castellani, C., & Edwards, M. *Marine Plankton: A Practical Guide to Ecology, Methodology, and Taxonomy*.
- Lalli, C. M., & Parsons, T. R. *Biological Oceanography: An Introduction*.sciencedirect+1
- Mann, K. H. *Ecology of Coastal Waters, with Implications for Management*.

Paper II Benthic Ecology and Coastal Ecosystems (Credits - 4)

Module I

Introduction to Benthic Ecology - Benthic environment, Classification of benthos, Benthic habitats, Determinants of benthic community structure, Sediment characteristics, Organic matter, Oxygen availability, Biological interactions

Module II

Intertidal Ecology - Intertidal environment, Physical stressors, Ecological adaptations, Rocky shores, Sandy shores, Mudflats, Intertidal zonation, Community succession

Module III

Coastal Marine Ecosystems – Estuaries, Coastal lagoons, Salt marshes, Mangrove ecosystems, Sand dunes, Coastal wetlands, Ecological functions, Ecosystem services

Module IV

Coral Reef and Kelp Forest Ecosystems - Coral reef ecology, Reef formation, Coral reef biodiversity, Zonation patterns on reefs, Coral reef productivity, Threats to coral reefs, Kelp forests, Ecological importance of kelp ecosystems

Module V

Benthic Ecosystem Functioning and Conservation - Energy flow in benthic ecosystems, Nutrient cycling, Benthic productivity, Benthic biodiversity, Ecosystem resilience, Human impacts on benthic habitats, Coastal habitat conservation, Ecosystem restoration, Blue Carbon ecosystems, Introduction to benthic environmental monitoring

Reference List

- Godson, P. S., Vincent, S. G. T., & Krishnakumar, S. *Ecology and Biodiversity of Benthos*.
- Bertness, M. D. (ed.). *Marine Community Ecology and Conservation*.
- Nybakken, J. W., & Bertness, M. D. *Marine Biology: An Ecological Approach*.
- Alongi, D. M. *The Energetics of Mangrove Forests*.

- Moberg, F., & Folke, C. *Ecological Goods and Services of Coral Reef Ecosystems*.

Suggested Practicals

Practicals I

1. Determination of dissolved oxygen and calculation of oxygen saturation.
2. Construction and interpretation of calibration curves.
3. Determination of carbonate/bicarbonate relationships from given seawater data.
4. Calculation of nutrient ratios and interpretation using Redfield stoichiometry.
5. Interpretation of vertical profiles of temperature, salinity, oxygen and nutrients.
6. Field visit to a nearby estuary and collection and analysis of pH, salinity, DO, alkalinity, nutrients.

Practical II

- Estimation of chlorophyll-a
- Estimation of primary productivity (Light–Dark bottle demonstration)
- Phytoplankton and Zooplankton identification, Measurement of plankton biomass
- Field visit to an estuary, mangrove, intertidal shore, or coastal wetland
- Benthic sampling methods (Grab sampler, Corer, Quadrat)
- Identification of benthic organisms
- Assessment of benthic biodiversity
- Intertidal zonation study
- Mangrove species identification

MDC- Environmental and Biodiversity Laws and Sustainable Development Goals (Credits – 3)

Module I

Fundamentals of Environment and Environmental Governance - Meaning and definition of Environment, Nature and Ecosystem, Components and functions of ecosystems, Origins and sources of Environmental Law, Principles of Environmental Law, Environmental Governance: Concepts and objectives, Environmental governance in international and national contexts

Module II

Introduction to International Environmental Agreements and Marine Protection - International environmental law and multilateral environmental agreements (MEAs), International

Convention for the Prevention of Pollution from Ships (MARPOL), Montreal Protocol on Substances that Deplete the Ozone Layer, International Convention for the Regulation of Whaling, International Whaling Commission (IWC), Convention on the Conservation of Migratory Species of Wild Animals (CMS/Bonn Convention), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Ramsar Convention on Wetlands

Module III

Climate Change and Sustainable Development - Meaning and definition of Sustainable Development, Brundtland Commission Report (Our Common Future), Rio Declaration, 1992, United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol, Paris Agreement, Sustainable Development Goals (SDGs), 2015, Blue Economy and sustainable ocean governance

Module IV

Biodiversity Conservation and Biosafety - Convention on Biological Diversity (CBD), Cartagena Protocol on Biosafety, Ecosystem conservation approaches, Access and Benefit Sharing (ABS), Conservation of marine and coastal biodiversity, Protected Areas and Biosphere Reserves, Marine Protected Areas (MPAs)

Module V

Environmental Legislation in India - Constitutional provisions for environmental protection, Biological Diversity Act, 2002, National Biodiversity Authority (NBA), National Biodiversity Tribunal (NBT), State Biodiversity Boards (SBBs), Biodiversity Management Committees (BMCs), People's Biodiversity Registers (PBRs), Coastal and marine biodiversity conservation in India, Environmental governance and policy implementation in India

Reference List

1. Birnie, Boyle & Redgwell – *Principles of International Environmental Law*
2. Divanshu & Rosencranz – *Environmental Law and Policy in India*
3. Meadowcroft et al. – *Environmental Governance: Approaches, Policies and Strategies*
4. Bodansky, Brunnée & Rajamani – *International Environmental Law and Policy*
5. Boyle – *Marine Environmental Law*
6. WCED – *Our Common Future*
7. Hollo et al. – *Climate Change and International Environmental Law*
8. Pauli – *Blue Economy: Sustainable Development of the Oceans*
9. Jeffries – *Biodiversity and Conservation*
10. Segger – *The Cartagena Protocol on Biosafety*
11. Leelakrishnan – *Environmental Law in India*

12. NBA – *Biological Diversity Act, 2002 Commentary*

Suggested Practical

Case Studies

Multi-Disciplinary Course

OS-MDC-201 Partial Derivatives, Multiple Integrals, Trigonometry And Matrices

Module: I

Multiple Integrals

Double Integrals, area of bounded region in plane only, Double Integrals in Polar form, Triple integrals in rectangular co-ordinates, Volume of a region in space

Module: II

Trignometry

Expansions of sin $n\theta$, cos $n\theta$, tan $n\theta$, $\sin^n \theta$, $\cos^n \theta$, $\sin^n \theta \cos^m \theta$ Circular and hyperbolic functions, inverse circular and hyperbolic function. Separation into real and imaginary parts. Summation of infinite series based on C+iS method. (Geometric, Binomial, Exponential, Logarithmic and Trigonometric series).

Module: III

Partial Derivatives

Functions of several variables (Definition only), Partial derivatives, The Chain Rule

Module: IV

Matrices

Rank of a Matrix, Non-Singular and Singular matrices, Elementary Transformations, Inverse of an elementary Transformations, Equivalent matrices, Row Canonical form, Normal form, Elementary matrices only.

Systems of Linear equations: System of non-homogeneous, solution using matrices, Cramer's rule, system of homogeneous equations, Characteristic equation of a matrix; Characteristic roots and characteristic vectors. Cayley-Hamilton theorem (statement only) and simple applications

Reference

1. George B. Thomas, Jr: Thomas' Calculus Eleventh Edition, Pearson, 2008.

2. Frank Ayres Jr: Matrices, Schaum's Outline Series, TMH Edition.

3. S.L. Loney-Plane Trigonometry Part – II, AITBS Publishers India, 200

Semester: III

DSC

OS-POC-301 Thermodynamics

Module: I

Behaviour of real gases

Behaviour of real gases -Change of state, Continuity of state, Andrew's experiments on Carbon dioxide -Critical constants- Vander Waals equation of state-Comparison with experimental PV curves-Estimation of critical constants – Constants of Vander Waals equation -Critical coefficient -Limitations of van der Waals equation.

Module: II

Thermodynamic system

Thermodynamic system- Zeroth law (Statement and explanation)-Thermodynamic equilibrium- First law of thermodynamics- Applications of first law-Specific heats of a gas, isochoric process, isobaric process, adiabatic process, adiabatic equation of a perfect gas, cyclic process, isothermal process-Indicator diagram- Work done during isothermal and adiabatic process- slopes of adiabatics and isothermals- relation between adiabatic and isothermal elasticities.

Module: III

Heat engines

Reversible and irreversible process- Heat Engines-Carnot's ideal heat engine-Carnot's cycle Effective way to increase efficiency-Carnot's engine and refrigerator-coefficient of performance -Second law of thermodynamics-Kelvin's and Clausius's statement-Carnot's theorem.

Module: IV

Thermodynamic relations

Entropy- change in entropy- entropy change in adiabatic process and reversible cycles Principle of increase of entropy- The T-S diagram- Physical significance of entropy- Entropy of steam- Third law of thermodynamics: Nernst's Heat Theorem-Zero-point energy.

Thermodynamic potentials- Significance of thermodynamic potentials- relation of thermodynamic potentials with their variables- The TdS equations- Clapeyron's Latent heat equation using Maxwell's Thermodynamical relations.

Module: V

Thermal Radiation

Thermal radiation- Prevost's theory of heat exchanges- Black body- Fery's black body- Blackbody radiation and its temperature dependence- Emissive power and absorptive power-

Stefan –Boltzmann law- Conduction, thermal conductivity, thermal conductivity of bad conductor Lee's disc experiment -thermal resistance.

Reference

1. Thermodynamics and Statistical physics Brij Lal, Subrahmanyam and P S Hemne, (S. Chand &Co, Multi colour edition 2007, Chapters 5,6 and 8

OS-POC-302 Introduction to Oceanography

Module: I

General Introduction-Ocean and Sea-Major Oceans and its dimensions -seafloor features-shoreline-Continental Shelf-Continental Slope-Continental Rise-Mid ocean Ridges-Seamounts- Guyots-Trenches-Island Arc-Atolls- Hydrothermal Vents and Cold Seeps-Geoid.

Module: II

Composition of Earth- Crust, Mantle and ore- Continental and oceanic crust- Ocean basins and bottom materials- Turbidity currents- Submarine Canyons- Plate tectonics- Continental drift and sea floor spreading-Pangea-Gondwana-Evolution of the Indian Coast- Methods for mapping bottom topography- Paleo oceanography.

Module: III

Marine sediments-sources and types- Lithogenous, biogenous, hydrogenous and cosmogenous sediments-classification of sediments based on grain size.

Module: IV

Physical properties of sea water-Molecular properties of water- Pressure-Temperature-Salinity and Conductivity-Density of sea water-Effects of temperature and salinity on density-Potential density- Specific volume and specific volume anomaly - Sound in the sea- Light in the sea- Colour of sea water- Chemical composition of sea water, Major nutrients and dissolved gases.

Module: V

Introduction to biological oceanography-Food Chain-Primary Productivity-Phytoplankton and zooplankton- Nekton and Benthos -Biological pump-Fishes, Marine mammals - Algal blooms and HAB.

Module: VI

History of Oceanography-Exploring Oceans- Major Expeditions in oceanography-Challenger Expedition-METEOR and DISCOVERY Expeditions-International Geophysical Year (IGY)-International Indian Ocean Expedition (IIOE)-Monsoon Experiments in Indian Ocean-MONEX- BOBMEX-ARMEX- Tropical Ocean Global Atmosphere (TOGA) World Ocean Circulation Experiment (WOCE) - Joint Global Ocean Flux Studies (JGOFS)

Reference:

1. Pickard G.L. and W.J. Emery (1995): Descriptive Physical Oceanography- Pergamon press, (1995or latest edition).

2. Lynne D. Talley, G.L. Pickard, W.J. Emery and James Swift (2011): Descriptive Physical Oceanography: An Introduction- Elsevier (6th edition, 2011).

3. Robert H. Stewart (2003): Introduction to Physical Oceanography- online edition (public domain), Aug 2003.

4. Open University Course team and Butterworth-Heinemann (1997): Sea water, its composition, properties and behavior; Open University team, 2nd Edition, 1997, jointly published by Oxford, UK, ISBN 0-7506-3715-3

5. Alan P. T and Harold V. T. (2014) Essentials of Oceanography, Eleventh Edition

6.Tomczak M. &J.S.Godfrey (2003) Regional Oceanography an Introduction second edition

OS-POE-301 Introduction to Atmospheric Physics

Module: I

Sun, Earth and the Atmosphere-Sun-Earth relationship, solstices and equinoxes, motion of earth - vertical thermal structure of the atmosphere, composition of the atmosphere - dry air, water vapour and aerosols. Atmospheric Optics - Visibility - attenuation of light-turbidity, Optical phenomena - rainbows, haloes, corona, glory, mirage etc. scattering - blue of the sky colours at sun rise and sunset- atmospheric refraction.

Module: II

Radiation- laws of black body radiation, radiation transfer. Solar radiation - latitudinal and seasonal variations-passage through the atmosphere-absorption - scattering and reflection - Mean disposition of solar radiation. Terrestrial Radiation absorption in the atmosphere - atmospheric window - radiative heat exchange-influence of clouds on radiation fluxes-influence of aerosols, radiative cooling of atmosphere, aerosol on scattering and their impact on direct and diffuse radiation, diurnal minimum and maximum temperature. Mean heat balance of the earth- atmosphere system, atmospheric green-house effect - poleward transport of energy-fundamental link with the general circulation.

Module: III

Gas laws and their application to the Atmosphere-Equation of state for dry and moist air-humidity parameters-virtual temperature. First and second laws of thermodynamics-specific heats of gases- internal energy-adiabatic processes-potential temperature-entropy-reversible and irreversible Processes-Carnot’s cycle. Thermodynamics of water vapour-latent heat-the

Clausius-Clapeyron equation. Thermodynamics of the atmosphere-dry adiabatic lapse rate-case of unsaturated moist air saturated adiabatic lapse rate, pseudo-adiabatic cases-equivalent potential temperature-thermodynamics of the wet-bulb thermometer-wet-bulb potential temperature and saturation potential temperature- Normand's Propositions-Normand point.

Module: IV

Hydrostatics of the Atmosphere-Geopotential, equipotential Surface-Hydrostatic equation-hydrostatic equilibrium, standard atmosphere - altimetry. Thermodynamic diagrams-basic requirements-emagram, skew T-log P diagrams-tephigram-use of tephigram for height calculations in aerological soundings

Module: V

Atmospheric instability and Convection-Stability Criteria- CAPE and CINE - parcel method - Brunt- Vaisala oscillations, lifting, mixing and convective condensation levels-potential instability and latent instability-stability indices-slice method of stability analysis- growth of cumulus clouds-entrainment.

Reference

1. Atmospheric Thermodynamics (Second Edition), J V Iribarne & W L Godson, Springer, 1981.

2. Physics of Atmospheres (Third Edition), J Houghton, Cambridge University Press, 2002.

3. Fundamentals of Atmospheric Physics, Murry L Salby, Academic Press, 1996.

4. Clouds, Rain and Rain Making (second Edition), B J Mason, Cambridge University Press, 2010.

5. Thermodynamics of Atmosphere and Ocean, J. Curry and P.J. Webster, Academic Press, 1998.

6. The Atmosphere: a very short introduction, Paul I. Palmer, 2017.

OS-POE-302 Vector Calculus, Differential Equations and Analytic Geometry

Module: I

Vector Valued functions

Vector Functions, Arc length and unit Tangent vector T, Curvature and unit Normal Vector N, Torsion and unit Binormal vector B, Directional Derivatives and Gradient Vectors.

Module: II

Integration in Vector Fields

Line Integrals, Vector fields and Work, Circulation and Flux, Path independence, Potential Function and Conservation Fields, Green's theorem in Plane (Statement and problems only), Surface area and Surface integral, Parameterised Surface, Stokes theorem (Statement and

Problems only), the Divergence theorem and a Unified theory (Statement and simple problems only).

Module: III

Ordinary differential equations

Exact Differential Equation, Linear Equations, Solutions by Substitutions, Equations of first order and not of first degree, First order equations of higher Degree solvable for p, Equations solvable for y, Equations solvable for x, Equations of first degree in x and y , Lagrange's and Clairaut's Equation.

Module: IV

Analytic Geometry

Conic sections and Quadratic equations, Classifying Conic Sections by Eccentricity, Conics and Parametric equations, The Cycloid, polar co-ordinates, Conic Sections in Polar coordinates.

Reference

1. A. H Siddiqi, P Manchanada: A first Course in Differential Equations with Applications (Macmillan India Ltd 2006)

2. George B. Thomas, Jr: Thomas' Calculus Eleventh Edition, Pearson, 2008.

Minor: Marine Chemistry

OS-MMC-301 Marine Chemistry

Module: I

Ocean as a Chemical System

History of oceanography, important oceanographic expeditions and oceanographic institutions of the world. Origin of seawater, structure of water, ion-water interactions, the polarized water molecule, colligative properties of seawater, comparison of river and sea water, hydrological cycle and budget.

Module: II

Classification of elements based on their distribution

Composition of sea water, salinity and chlorinity concepts, the major and minor constituents, constancy of relative composition, behavior of elements - chemical exchanges across interfaces and residence times in seawater, geochemical balance of oceans. Primary, cosmogenic and artificial nuclides, Applications of radioisotopes in oceanography

Module: III

Dissolved gases in sea water.

Factors affecting the concentration of gases in seawater, pH, alkalinity, specific alkalinity, buffer capacity, sea water - carbon dioxide equilibria, precipitation and dissolution of carbonates, global carbon cycle. Biological pump and controls on atmospheric composition - emission of greenhouse gases.

Module: IV

Micronutrients

Nitrogen, phosphorus and silicon, their cycles, distribution profiles and their effect on phytoplankton growth, N/P ratio

Organic matter in the sea

Dissolved and particulate: Nature, origin and distribution, Photosynthesis and Primary production.

Module: V

Practical: Water Quality Analysis. Sampling of water (microlayer, surface , sub-surface) and sediment (surficial and sub surface), Filtration and storage of samples.

Determination of Salinity, Dissolved oxygen, BOD, COD, pH, Eh, Alkalinity, hardness, Nutrients (nitrate, nitrite, ammonia, urea, phosphate, silicate), Pigments, TOC, POC, SOC.

Sample preparations, handling and determination of trace metals in environmental samples.

References:

A. C. Duxbury, A. B. Duxbury, K. A. Sverdrup, An Introduction to World Oceans, 6thEd.,

McGraw-Hill, 2000.

2. T. Garrison, Oceanography, 2nd Ed., Wadsworth Publishing, 1995.

3. F. J. Millero, Chemical Oceanography, 2nd Ed., CRC Press, 1996 or 3rd Ed., CRC

Press 2006.

4. J. P. Riley, R. Chester, Introduction to Marine Chemistry, Academic Press, 1971.

5. Seawater: Its Composition, Properties and Behaviour, The Open University

Oceanography Series, Pergamon, 2nd Ed., 1995.

6. J. P. Riley, G. Skirrow, Chemical Oceanography, Vols. I to III, Academic

Press,1975.

7. K. Grasshoff, K. Kremling, M. Ehrhardt Ed., Methods of Seawater Analysis, 3rd

completely revised and extended edition, Wiley-VCH, 1999.

8. APHA, Standard Methods for the Examination of water and waste water, 22nd Edn. 2012.

9. IOC Manuals and Guides -12. Chemical methods for use in Environmental Monitoring, UNESCO, 1983.

10. IOC Manuals and Gudes – 15. Procedures for sampling Sea Surface Micro – layer,

UNESCO. 1985.

11. J.D. Strickland and T.R. Parsons. A Practical Handbook of Sewater Analysis,

Unipub,1084.

12. T.R. Parsons, Y. Maita and C. M. Lalli. A manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press. 1984

Minor: Marine Biology

IMB3-MB-DSC3-101 Marine Biodiversity I: Invertebrates and Reef Ecology

Module: I

Introduction to Marine Biodiversity and Invertebrates

Concept and scope of marine biodiversity; classification and diversity of marine organisms; importance of marine invertebrates in ecosystem functioning; evolutionary trends in marine invertebrates; principles of taxonomy and systematics; marine biogeographic regions; ecological roles of invertebrates in marine ecosystems; Marine zoogeography

Module: II

Lower Marine Invertebrates

General characteristics and classification of Protozoa; Porifera; Cnidaria and Ctenophora; organization and functional adaptations; feeding and reproduction; ecological importance of sponges and cnidarians; coral-forming organisms; jellyfish blooms and ecological impacts; symbiotic associations in lower invertebrates.

Module: III

Higher Marine Invertebrates

General characteristics and classification of Platyhelminthes; Annelida; Arthropoda; Mollusca and Echinodermata; adaptive radiation in marine invertebrates; larval forms and dispersal; ecological and economic importance of crustaceans and molluscs; benthic ecology; commercially important marine invertebrates.

Module: IV

Reef Ecology and Coral Reef Ecosystems

Coral reef formation and distribution; types of coral reefs; reef-building corals and symbiosis with zooxanthellae; reef biodiversity and trophic interactions; reef productivity and nutrient

cycling; reef-associated fauna and flora; reef fish interactions; threats to coral reefs; coral bleaching; reef restoration and conservation strategies.

Module: V

Conservation and Applied Aspects of Marine Biodiversity

Marine biodiversity assessment methods; biodiversity indices; marine protected areas; endangered marine invertebrates; invasive marine species; conservation of coral reef ecosystems; sustainable utilization of marine biodiversity; role of marine biodiversity in fisheries and biotechnology; ecosystem-based conservation approaches.

Practicals

Identification and classification of marine invertebrates; study of larval forms; preparation of taxonomic keys; observation of coral reef organisms; biodiversity estimation methods; preparation of reef ecosystem charts; field visit to rocky shore, estuary or reef-associated ecosystem; maintenance of biodiversity records.

References

1. Castro, P. & Huber, M. E. *Marine Biology*. McGraw-Hill Education.
2. Brusca, R. C., Moore, W. & Shuster, S. M. *Invertebrates*. Sinauer Associates.
3. Loya, Y. et al. *Coral Reef Ecology*. Springer.
4. Russell, F. E., Nagabhushanam, R. *The Venomous and Poisonous Marine Invertebrates of the Indian Ocean.* United States: Science Publishers.
5. Walls J. G. *Encyclopaedia of Marine Invertebrates*, TFH Publications
6. Richard C. Brusca, *Invertebrates*, Sinauer Associates
7. Krishnamoorthy Venkataraman, Chandrakasan Sivaperuman, *Marine Faunal Diversity in India- Taxonomy, Ecology and Conservation*, Academic Press
8. Zoological Survey of India faunal series and marine biodiversity publications.

Value Added Course

OS-VAC-301 Hydro-chemical Assessment Techniques

1. Sampling of seawater (surface/sub-surface) samples
2. Filtration and storage of samples
3. Determination of salinity (chemical method)
4. Determination of dissolved oxygen
5. Determination of BOD and COD
6. Determination of pH, Eh and alkalinity

7. Determination of nutrients – nitrate, nitrite, phosphate and silicate

8. Determination of pigments (Chlorophyll a, b, c and phaeopigments)

9. General methods of determination of cations in seawater using a flame photometer.

10. Estimation of trace metals using AAS practical demonstration

References

1. K.Grasshoff. M. Ehrhardt and K. Kremling. Methods of Seawater Analysis 3rd edn., Wiley-VCH, 1999

2. APHA, Standard Methods for the Examination of Water and Wastewater, 23rd ed., 2017

3. IOC Manuals and Guides-12. Chemical Methods for use in Marine Environmental Monitoring, UNESCO. 1983

4. IOC Manuals and Guides-15. Procedure for Sampling Sea Surface Micro-layer, UNESCO, 1985

5. J.D. Strickland and T.R. Parsons. A Practical Handbook of Seawater Analysis, Unipub, 1984

6. T.R. Parsons, Y. Maita and C.M.Lalli. A Manual of Chemical and Biological Methods for Seawater Analysis, Pergamon Press, 1984

7. T.R. Crompton. Analysis of Seawater: A Guide for the Analytical and Environmental Chemist. Springer, 2006

Multi-Disciplinary Course

OS-MDC-301 Descriptive Statistics

Module: I

Introduction to Statistics, Population and Sample, Collection of Data, Various methods of data collection, Census and Sampling. Methods of Sampling – Simple Random Sampling– stratified sampling – systematic sampling (Method only), Types of data – quantitative, qualitative, Classification and Tabulation, Frequency Table, Diagrammatic representation – Bar diagram, pie diagram; pictogram and cartogram.

Module: II

Measures of Central Tendency – Mean; Median; Mode; Geometric Mean; Harmonic Mean and Properties, Partition values- Quartiles, Deciles, Percentiles, Absolute and Relative measures of Dispersion – Range, Quartile Deviation, Box Plot, Mean Deviation, Standard

Deviation, Coefficient of Variation. Graphical representation – histogram, frequency polygon, frequency curve, ogives and stem and leaf chart.

Module: III

Correlation and Regression: Simple Correlation- Scatter diagram, Karl Pearson's co-efficient of correlation, Spearman's Rank correlation. Simple linear regression, Regression lines- Identification of regression lines.

Module: IV

Testing of hypothesis-Null and alternate hypothesis, significance level, power of the test, Z tests for means and proportion (one sample and two samples).

Module: V

Sampling distributions, Standard Error, Chi-square, Students t and F distributions. Confidence interval for the mean and proportions. Tests of Significance concerning Mean, Proportion and Variance. Non-parametric procedures- Chi-square tests, Kolmogorov-Smirnov test and Run test.

Reference:

1. Gupta and Kapoor (2000): Fundamentals of Mathematical Statistics.
2. Croxton F.E. and Cowden D.J.(2000): Applied General Statistics. Prentice Hall.
3. Kendall M.G and Stuart A.: The advanced theory of statistics. Vol. I & I
4. S. P. Gupta: Statistical Methods, Sultan Chand and Sons, New Delhi.
5. 2. S.C. Gupta and V.K. Kapoor : Fundamentals of Mathematical Statistics, Sultan Chand
6. and Sons.
7. 3. Fundamentals of Statistics: DN Elhance, Kitab Mahal, Allahabad.

Semester IV

Major: DSC

OS-POC-401 Geophysical Fluid Dynamics

Module: I

Basic concepts- fluids: fluid continuum, fluid properties, ideal fluid, actual fluids, types of flow; statics: pressure surface and body forces on a fluid element; fundamental equation of fluid statics: application to compressible and incompressible fluids, perfect gas equation, hydrostatic equation.

Module: II

Kinematics: Lagrangian and Eulerian methods of description of fluid flow- stream lines- streak lines and trajectories- steady and non-steady flow- decomposition of the field of motion in the vicinity of a point- translation, rotation- divergence and deformation- stream function, divergence and vorticity- local and convective derivatives.

Module: III

Dynamics: equation of continuity and its applications- non-viscous incompressible flow- Eulerian equations of motion- inertial and rotational frames of reference- Coriolis force, irrotational flow- velocity potential- integration of the equations of motion- Bernoulli's theorem and its applications.

Module: IV

Viscous fluids- coefficient of viscosity- Navier-Stoke's equations of motion for a viscous Newtonian fluid- laminar flow of viscous incompressible fluids- Reynold's number and dynamic similarity of flows- physical significance of Reynold's number, low and high Reynold's number.

Module: V

Circulation and vorticity- Stoke's theorem- Kelvin's theorem- barotropic and baroclinic fluids- absolute and relative circulation- Bjerknes circulation theorem and interpretation

Reference

1.S.W. Yuan (1967): Foundations of Fluid Mechanics
2. J. Pedlosky (1987): Geophysical Fluid Dynamics
3. G.K. Batchelor (1967) An introduction to Fluid Mechanics
4. S. L. Hess (1959) An introduction to Theoretical Meteorology
5. Samual A. Elder and J. Williams (1989) Fluid Physics for Oceanographers and Physicists.
6. Benoit Cushman-Roisin and Jean-Marie Beckers (2009): Introduction to Geophysical Fluid Dynamics. Physical and Numerical Aspects

Major: DSE

OS-POE-401 Remote Sensing of Oceans

Module: I

Introduction to Remote Sensing - Basic concepts – principles of aerial photography - electromagnetic radiation – solar and terrestrial radiation - atmospheric effects – absorption, transmission and scattering – spectral response of earth's surface features – atmospheric windows-concept of signature.

Module: II

Satellites-classification based on orbits and purpose-different types of sensors-Optical Remote Sensing-optical pathways in atmosphere-strategies for atmospheric correction of visible wave length data-scattering and absorption of light in sea water-oceanographic interpretation of ocean colour-light scattering at sea surface-important ocean colour sensors. Infrared Remote Sensing: thermal emission – atmospheric absorption – IR sensors – SST retrieval – atmospheric correction-effect of cloud – thermal skin layer – skin and bulk SST.

Module: III

Microwave Remote Sensing: theory of microwave radiometry – microwave emission of sea surface – atmospheric effects – retrieval of salinity and wind vector – passive microwave radiometers: SMMR, SSM/I, TRMM/TMI and AMSR – active microwave radiometers: microwave interaction with the sea surface – NSCAT, Sea Winds -– Altimetry: principles – sea surface height anomaly – ERS, T/P, Jason-1 – observing planetary waves and eddy energy.

Module: IV

Applications of AVHRR, Altimeters, SAR- Monitoring of SST, geostrophic currents, mesoscale variability, eddies, fronts, upwelling, Sea ice Satellite Capabilities-Global scale coverage- Different types of satellite data products available SeaWiFS, MODIS, OCM-1& 2, SARAL- Altika, TOPEX-Poseidon, ERS 1 & 2, JASON, QuikScat, etc.

Module: V

Definition of GIS – components of GIS – Geographical concepts – Input data for GIS – Types of output products, Application of GIS – GIS Data types – Data representation – Data sources – Data acquisition – Geo referencing of GIS data – Spatial data errors – Spatial data structures. Essential Goal of Marine GIS, Spatial Thinking and GIS Analysis in the Marine Context, Conceptual Model of a Marine GIS.

Digital image processing technique-image enhancement-unsupervised and supervised classification methods (Assignment)

Reference:

1. I.S. Robinson: (1985) Satellite Oceanography- An Introduction for Oceanographers and Remote Sensing Scientists.
2. Seelye Martin (2014): An Introduction to Ocean Remote Sensing, 2nd Edition, Cambridge Press
3. Motoyoshi Ikeda and Frederic W. Dobson (1995). Oceanographic Applications of Remote Sensing, CRC Press, USA.
4. Robert H.Stewart (1985) Methods of Satellite Oceanography
5. T.D. Allan (1983) Satellite Microwave Remote Sensing
6. G.A. Maul (1985) Introduction to Satellite Oceanography
7. I. S. Robinson (2004) Measuring the Oceans from space: The principles and methods of satellite Oceanography.

OS-POE-402- Fourier Series, Partial differential Equations,

Numerical Analysis and Abstract Algebra

Module: I

Special Functions

Fourier Series: Periodic Functions, Trigonometric Series, Functions of any period p = 2L Fourier Series, Even and Odd functions, Half-range Expansions. Legendre Polynomials - A brief introduction to power series and power series method solving Differential equations. Legendre equation and Legendre Polynomials, Rodrigues Formula, Bessel's Equation, Bessel's Functions.

Module: II

Partial Differential Equations

Surfaces and Curves in three dimensions, Origin of first order and second order partial differential equations, Linear equations of the first order, Lagrange's method.

Module: III

Numerical Analysis

Bisection Method, Methods of false position, Iteration Method, Acceleration of convergence: Aitken's Δ^2 Process, Newton Raphson Method, the quotient- Difference method.

Module: IV

Abstract Algebra

Groups, Subgroups, Cyclic groups, Groups of Permutations and Homomorphisms, Rings and Fields, Vector Spaces. (Theorems Statement only. Omit Proofs).

Reference

1. Erwin Kreyszig: Advanced Engineering Mathematics, Eighth Edition, Wiley, India.
2. Ian Sneddon – Elements of Partial Differential Equation (Tata McGraw Hill)
3. S.S. Sastry: Introductory methods of Numerical Analysis ,4th edition (Prentice Hall)
4. 4. John B Fraleigh- A first course in Abstract Algebra (7th Edition) Pearson Education

Minor: Marine Chemistry

OS-MMC-401 Biogeochemistry

Module: I

Introduction, overview and concepts:

Major element cycles in the deep ocean, Mass balance between river input and oceanic sediment outputs for minor and trace elements. Oceanic circulation and chemistry, Biological Pump, Primary Production in the ocean, nutrient supply, Use of nutrients as water mass tracers, primary producers, seasonal cycles, spring bloom, nitrogen fixation. The Iron hypothesis, Elemental Stoichiometry and Redfield ratio. Influence of biota on the geochemical cycling of inorganic and organic substances through the atmosphere, hydrosphere, and lithosphere.

Module: II

Biogeochemical Cycles:

Biogeochemical cycles of carbon, nitrogen and sulfur. The oceanic carbonate system, global ocean-atmosphere interactions, biogeochemical cycles and climate change. Biogeochemistry of carbon, sulfur, selected metals, and organic compounds of natural and anthropogenic origin. The carbon cycle, The sulfur Cycle.

Module: III

Isotope effects:

Mass dependent and mass independent effects, Isotope geothermometers, Isotope fractionation in the geochemical cycles of carbon and sulfur. Relations among isotope age curves, Stable isotope variations of Heavy elements, Si, P and Fe Biogeochemical cycles.

Module: IV

Climate change effects/feedbacks on C-cycle:

Air-sea carbon dioxide fluxes, Ocean acidification and carbonate chemistry, Effect of ocean acidification on the speciation of metals in seawater, Benthic processes of biogeochemical cycles. UVR effects on aquatic ecosystem: a changing climate perspective.

Module: V

Practical: General sediment quality Analysis

Protocols for the collection, storage and handling of sediments samples.

Determination of pH, Eh, TOC, Trace metals, Nutrients, Proteins, Lipids, Carbohydrate, Pigments and pollutants from sediments.

References:

1. Libes, S.M. (2009). Introduction to Marine Biogeochemistry. Elsevier, Amsterdam.

2. William H. Schlesinger and Emily S. Bernhardt, Biogeochemistry: An Analysis of

Global Change. Academic Press, 3rd Edition, 2013

3. Chemical cycles in the evolution of the earth. C.B. Gregor, R.M. Garrels, F.T.

Mackenzie and J.B. Maynard.

4. Stable Isotope geochemistry, JochenHoefs (VI th Ed) Springer, 2009.

5. UV effects on aquatic organisms and ecosystems – E.W Helbling and H Zagarese

(VolEdts)– Donat Peter Hader and GuilioJori, 2003.

6. Chemical Oceanography, Frank J Millero (4th Edn) CRC Press, 2013.

7. IOC Manuals and Guides-13.Manual for monitoring Oil and Dissolved/Dispersed Petroleum Hydrocarbons in Marine Waters and on Beaches UNESCO, 1984
8. Aquatic Environment Analytical Methods. Methods of Analysis of Hydrocarbons in Marine and Protection: Other Samples, MAFF, 1988
9. Aquatic Environment Analytical Methods. Methods of Analysis of Trace Metals in Marine and Protection: Other Samples, MAFF, 1989
10. J.Bassett, R.C. Denney, G.H.Jeffery and J.Mendham. Vogel's Text Book of Quantitative Inorganic Analysis 4th edn., ELBS, 1982.

OS-MMC-402 Marine Pollution

Module: I

Marine Pollution

Definition, Categories of additions, Pollutant and its classification. Organic wastes: BOD, COD, dilution factor, Fluctuations in DO, Consequences of organic discharges to estuaries with examples; Sewage treatment: Primary, Secondary and Tertiary treatment processes. Solid waste pollution: Classification and disposal of solid wastes.

Module: II

Marine Pollution II

Oil spills and cleanup: Sources, Major accidental spills, fate of spilled oil on the sea, consequences of oil spills and treatment of oil spills.

Pesticide pollution: inputs, fate in the sea, factors affecting the bioaccumulation of pesticides, DDT the most wide spread molecule, Impact of pesticides on the Environment, Mode of poisoning of pesticides, Methods to minimize pesticide pollution.

Conservative pollutants: Measures of contamination, toxicity, measurement of toxicity, acute and chronic exposure, Detoxification. Metal pollution in coastal waters (Hg, Pb, Cd, Cu, Zn and Fe).

Radioactive Pollution: Sources, Classification and effects of radiation; Protection and control from radiation: Maximum permissible dose concept, dose limits, Disposal of radioactive wastes; Beneficial aspects of radiation and food safety.

Module: III

Industrial Pollution

Sources, nature and their treatment processes with reference to wastes from paper and pulpand soap manufacturing industries.

Marine corrosion: Definition, corrosion reactions, classification of corrosion, factors affecting corrosion of metals in sea water and prevention of marine corrosion. The state of some seas in the world (pollution aspect); The North sea, The Mediterranean sea and the Baltic sea.

Module: IV

Monitoring Strategies

Indicator organisms: Criteria for selection of indicator organism: Quantisation of pollution load, basic pre-requisites, response to different pollution load and time integration capacity, Macro algae; crustaceans and mollusks as indicator organisms for monitoring of trace metal pollution; Red tides : distribution, types of poisoning, effects and methods to minimize red tides in the sea. Concepts of bioavailability, bio concentration and bio magnification. Monitoring strategies of marine pollution: Critical pathway approach and Mass balance approach.

Practicals: 1. Heavy metal extraction and determination effluents. 2. Pesticide extraction and determination.

References:

1. Riley J.P and Skirrow, G. 1975. Chemical Oceanography (Vol: 3)

2. Goldberg, E.D. 1976. The health of the oceans.

3. Clark, R.B. 1986. Marine Pollution.

4. Phillips J.D.H. 1980. Quantitative aquatic biological indicators.

5. Sharma, B.K and Kaur, H. 1994. Thermal and radioactive pollution.

6. Sharma, B. K and Kaur, H. 1994. Water Pollution.

7. Chandler, K.A. 1985. Marine and offshore corrosion.

8. Metcalf and Eddy. Waste water engineering, treatment and Resources recovery, 5th edn., McGraw-Hill Science, 2013.

9. J. Albaiges. Marine Pollution, Hemisphere Publ. Corp., 1989.

10. E.D. Goldberg. The Health of the Ocean, The UNESCO Press, 1976.

11. L. Landner. Chemicals in the Aquatic Environment, Springer Verlag, 1989.

12. P. Dent, Marine Pollution Year Book, Pergamon Press, 1990.

13. J.W. Moore and S. Ramamoorthy. Organic Chemicals in Natural Waters, Springer

Verlag, 1984.

14. J.W.Moore. Inorganic Contaminants of Surface Water, Springer Verlag, 1991.

15. D.W. Connell and G. J. Miller. Chemistry and Ecotoxicology of Pollution, John Wiley and Sons, 1984.

Minor: Marine Biology

IMB4-MB-DSC6-101 Marine Botany

Module: I

Introduction to Marine Vertebrates

Classification and diversity of marine vertebrates; evolutionary origin of vertebrates; adaptations to marine environments; zoogeographical distribution of marine vertebrates; ecological importance of marine vertebrates in marine ecosystems.

Module: II

Marine Fishes

General characteristics and classification of cartilaginous and bony fishes; morphology and functional adaptations; feeding and reproductive biology; migration in fishes; coral reef fishes and pelagic fishes; economically important marine fishes; fish behaviour and ecological interactions; Adaptations in fishes of different habitats: pelagic, coastal, coral, deep sea and polar regions.

Module: III

Marine Reptiles and Seabirds

Marine reptiles including sea turtles and sea snakes; adaptations of marine reptiles; nesting biology and migration; seabirds and their ecological significance; feeding ecology and breeding behaviour; threatened marine reptiles and seabirds; conservation strategies.

Module: IV

Marine Mammals

Classification and diversity of marine mammals; cetaceans, pinnipeds, sirenians and marine carnivores; anatomical and physiological adaptations to aquatic life; feeding ecology and migration; communication and social behaviour; marine mammal habitats and distribution; marine mammal strandings and rescue approaches; Biodiversity assessment methods of marine mammals

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Module: V

Conservation and Management of Marine Vertebrates

Threats to marine vertebrates including overfishing, bycatch, habitat destruction and pollution; climate change impacts; endangered marine vertebrates; marine protected areas; conservation laws and international conventions; marine mammal conservation in India; sustainable fisheries and ecosystem-based management.

Practicals

Identification of marine vertebrates; study of fish morphology; skeletal studies of fishes; identification of marine reptiles and seabirds; observation of vertebrate adaptations; preparation of taxonomic records; biodiversity assessment methods; field visit to fish landing centres, aquaria or coastal ecosystems.

References

1. Castro, P. & Huber, M. E. Marine Biology. McGraw-Hill Education.

2. Reeves, R. R. et al. Guide to Marine Mammals of the World. National Audubon Society.

3. Hoelzel, A. R. Marine Mammal Biology: An Evolutionary Approach. Blackwell Publishing.

4. Zoological Survey of India marine vertebrate faunal publications.

5. Central Marine Fisheries Research Institute marine fisheries and marine mammal publications.

IMB4-MB-DSC7-102 Marine Botany and Algal Diversity

Module: I

Introduction to Marine Botany and Marine Floral Diversity

Scope and importance of marine botany; marine primary producers and their ecological significance; classification of marine plants; marine habitats supporting floral diversity; introduction to phytoplankton, seaweeds, seagrasses and mangroves; role of marine vegetation in coastal productivity and ecosystem stability; distribution patterns of marine flora.

Module: II

Phytoplankton Diversity and Productivity

General characteristics and classification of phytoplankton; cyanobacteria; diatoms; dinoflagellates and coccolithophores; morphology and reproduction of phytoplankton; phytoplankton pigments; phytoplankton ecology and seasonal succession; primary productivity and carbon fixation; harmful algal blooms and red tides; ecological role of phytoplankton in marine food webs and biogeochemical cycles.

Module: III

Seaweeds and Marine Macroalgae

General characteristics and classification of green algae, brown algae and red algae; morphology and life cycle patterns; intertidal and subtidal seaweed communities; ecological importance of seaweeds; seaweed cultivation and mariculture; economically important seaweeds; agar, alginate and carrageenan industries; medicinal and nutraceutical importance of marine algae; seaweeds in bioremediation and blue biotechnology.

Module: IV

Seagrass and Mangrove Ecosystems

General characteristics and adaptations of seagrasses; distribution and ecological significance of seagrass meadows; productivity and ecosystem services of seagrasses; mangrove classification and zonation; physiological adaptations in mangroves; mangrove productivity and nutrient cycling; role of mangroves and seagrasses in shoreline stabilization, carbon sequestration and nursery ground formation; associated biodiversity.

Module: V

Conservation, Environmental Interactions and Applied Marine Botany

Threats to marine vegetation including habitat destruction, eutrophication, invasive species and climate variability; conservation and restoration of mangroves, seagrasses and seaweeds; marine floral diversity assessment methods; remote sensing applications in marine vegetation studies; marine plants in environmental monitoring; sustainable utilization of marine plant resources; blue carbon ecosystems and future prospects in marine botany.

Practicals

Identification of phytoplankton and marine algae; preparation of algal herbarium; study of seaweed morphology and reproductive structures; observation of mangrove and seagrass adaptations; estimation of chlorophyll and primary productivity; phytoplankton counting methods; field visit to mangrove, seagrass or intertidal ecosystem; preparation of marine floral diversity records.

References

1. Lee, R. E. Phycology. Cambridge University Press.

2. Lobban, C. S. & Harrison, P. J. Seaweed Ecology and Physiology. Cambridge University Press.

3. Larkum, A. W. D., Orth, R. J. & Duarte, C. M. Seagrasses: Biology, Ecology and Conservation. Springer.

4. Rao, P. S. N., Gupta, R. K. A Checklist of Indian Marine Algae (excluding Diatoms & Dinoflagellate). Botanical Survey of India

4. Kathiresan, K. & Bingham, B. L. Biology of Mangroves and Mangrove Ecosystems. Advances in Marine Biology.

Skill Enhancement Course

OS-SEC-401 Introduction to Python Programming

Module: I

Basics of Programming and Python

Introduction to programming concepts - Features and applications of Python - Installation of Python and IDEs - Python syntax and program structure - Variables, expressions, data types, and operators

Module: II

Control Structures and Functions

Conditional statements - Looping constructs - Break, continue, and pass statements - Functions and modular programming - Scope of variables - Built-in functions and modules

Module III

Data Structures and String Handling

Lists, tuples, sets, and dictionaries - String operations and methods - List comprehensions - Searching and sorting techniques

Module: IV

Object-Oriented Programming in Python

Introduction to Object-Oriented Programming - Classes and objects - Constructors and destructors

Inheritance – Polymorphism - Encapsulation and abstraction

Module: V

Files Handling, Scientific Computing and Visualization

Reading and writing files - CSV file handling - Exception handling using try-except-finally - Introduction to NumPy and Pandas - DataFrames and basic data analysis - Data visualization

References:

1. Downey, A., Elkner, J. and Meyers, C., 2008. *How to think like a computer scientist: learning with python* (Vol. 1). Green Tea Press.
2. Lambert, K.A. and Osborne, M., 2015. Fundamentals of PYTHON. *Cengage Learning, IE*.
3. Lambert, K.A. and Osborne, M., 2023. *Fundamentals of Python*. Cengage.

OS-SEC-402 Sampling Techniques in Marine Chemistry

1. Water sample collection techniques for DO, Salinity and Trace metals.
2. Instrumental operations for sample collection.
3. Heavy metal testing in local coastal zone.
4. Microplastic sample collection techniques.
5. Field visit for sample collection.

Reference

1. K. Grasshoff, M. Ehrhardt and K. Kremling. Methods of Seawater Analysis. 3Rd Edn.Wiley -VCH, 1999.

2. APHA, Standard Methods for the Examination of water and waste water, 22nd Edn. 2012.

3. IOC Manuals and Guides -12. Chemical methods for use in Environemntal Monitoring, UNESCO, 1983.

4. IOC Manuals and Gudes – 15. Procedures for sampling Sea Surface Micro – layer,

UNESCO. 1985.

5. J.D. Strickland and T.R. Parsons. A Practical Handbook of Sewater Analysis,

Unipub,1084.

Value Added Course

OS-VAC-401 Marine Natural Products Extraction Techniques

1. Extraction of marine natural organic compounds- Soxhlet extraction and PLE
2. Gas chromatography (GC) mass spectrometer, GC-Flame ionization detector, GCElectron Capture detector– Quantitative and qualitative analysis of volatile marine organic compounds.
3. Liquid Chromatography-Mass Spectrometer, HPLC-UV -analysis of high molecular weight and non-volatile organic compounds. Separation and purification of organic compounds using preparative HPLC.
4. Interpretation Exercises using spectra:
a) Interpretation of FTIR spectrum with reference to stretching vibrations of functional groups.
b) Absorption spectra (UV-VIS) reading and interpretation of chromophores
c) Interpretation of NMR spectrum with reference to the calculation of chemical shifts and general comments
d) Identification of molecular ions in Mass spectra

References

1. D.T.E. Hunt and A.L. Wilson. The Chemical Analysis of Water, 2nd ed., Royal Society of Chemistry, 1986
2. Instrumental Manuals of AAS, Fluorescence Spectrophotometer, GC and CHN Analyzer.
3. R.M. Silverstein and F.X. Webster, Spectrometric Identification of Organic Compounds, 6th ed., Wiley, 2006.

4. R. Dyer John. Applications of Absorption Spectroscopy of Organic Compounds, Prentice-Hall, 1978.
5. E. Pretsch, P. Bhlmann and M. Badertscher. Structure Determination of Organic Compounds, Springer-Verlag, 4th ed., 2009.

6. D.A. Skoog, D.M. West, F.J. Holler and S.R. Crouch. Fundamentals of Analytical Chemistry, 9th ed., Cengage Learning, 2013.
7. IOC Manuals and Guides-11. The determination of Petroleum Hydrocarbons in Sediments, UNESCO, 1982. R.M Silverstein, Spectrometric identification of organic compounds
8. IOC Manuals and Guides-13.Manual for Monitoring Oil and Dissolved/Dispersed Petroleum Hydrocarbons in Marine Waters and on Beaches UNESCO, 1984
9. Aquatic Environment Analytical Methods. Methods of Analysis of Hydrocarbons in Marine and Protection: Other Samples, MAFF, 1988
10. Aquatic Environment Analytical Methods. Methods of Analysis of Trace Metals in Marine and Protection: Other Samples, MAFF, 1989
11. J. Bassett, R.C. Denney, G.H.Jeffery and J.Mendham. Vogel's Text Book of Quantitative Inorganic Analysis 4th ed., ELBS, 1982.
12. Oliver Wurl. Practical Guidelines for the Analysis of Seawater. CRC Press, 2009.
13. T.R Chrompton, Analysis of Oceanic Waters and Sediments, CRC press, 2016

Semester: V

Major: DSC

OS-POC-501 Descriptive Physical Oceanography

Module: I

Space and time scales of physical oceanographic phenomena- Temperature and Salinity distribution in Oceans- Horizontal and Vertical structures and time variation of temperature-salinity -density-Sea level. Ocean mixed layer- barrier layer and thermal inversion-Thermocline, Halocline and Pycnocline- Seasonal and permanent thermocline- distribution of dissolved Oxygen-Oxygen minimum layer- Nutrients and other tracers and age of ocean water and turnover time.

Module: II

Conservation of salt and heat-T-S Diagram-Water type and water mass –Formation and classification of water masses- Major water masses- Bottom-Deep-Intermediate and surface water masses in the world oceans. Indian Ocean water masses-Red Sea-Persian Gulf and Mediterranean water masses.

Module: III

Ocean Circulation- Thermohaline and Wind driven Circulation- Importance of deep ocean circulation –Heat and fresh water transports - General circulation of World Oceans-Equatorial Currents, Undercurrent, Antarctic Circumpolar Current and Western and Eastern Boundary Currents, Langmuir Circulation.

Module: IV

Indian Ocean circulation- geographical features-wind pattern- Surface and sub-surface currents of the Indian Ocean- Seasonal cycle of currents in the north Indian Ocean-Currents in the Arabian Sea and Bay of Bengal- Currents off the east and west coasts of India- Somali current- Equatorial jet – Agulhas Current and retroflection. Lakshadweep High and Low-Intermediate and Deep Ocean circulation.

Module: V

Convergence and Divergence in Oceans- Upwelling and Sinking -Major upwelling regions of world oceans and Indian Ocean- Meso-scale Eddies and oceanic fronts. Southern Ocean Fronts and zones-Sea Ice. Large scale Oceanic variability-El Nino/La Nina, Southern Oscillation and Indian Ocean Dipole (Definitions only).

Reference: -

1. Pickard G.L. and W.J. Emery- Descriptive Physical Oceanography (1995): Pergamon press, (1995or latest edition).
2. Lynne D. Talley, G.L. Pickard, W.J. Emery and James Swift (2011): Descriptive Physical Oceanography: An Introduction- Elsevier (6^{th} edition, 2011).
3. Sverdrup H.U., Johnson M.W. and Fleming R.H (1958): The Oceans: their physics, chemistry and general biology, Prentice Hall Inc., New Jersey, 1958.
4. Robert H. Stewart- Introduction to Physical Oceanography (2003) : online edition (public

domain).

5.Tomczak M. &J. S. Godfrey (2003) Regional Oceanography an Introduction second edition

OS-POC-502 Dynamical Oceanography

Module: I

The basic conservation laws in dynamical oceanography-Dominant forces-Primary and secondary forces- Coriolis force-Co-ordinate systems-f palne, B plane and spherical coordinates-Types of flows in ocean- Conservation of mass and salt- barotropic and baroclinic fields- quasi static conditions, sigma-t surfaces-Specific volume and specific volume anomaly- thermosteric anomaly- Equation of continuity- Total derivative-Equation of continuity- application- Stability and double diffusion-Richardson Number-Buoyancy frequency- Boussinesq approximation.

Module: II

The equation of motion –with reference to Rotating frame – Coriolis force - gravity and Pressure gradient force. Nonlinear terms-Equation of motion with friction- Navier Stokes equation- Scaling the equations of motion- Reynolds number- Reynolds stresses and eddy viscosity- Rossby number- Ekman Number-Dynamic stability.

Module: III

Currents without friction- Inertial motion - Geopotential surfaces- Geostrophic flow-. Computation of geostrophic currents- Level of no motion-Advantages and limitations of geostrophic assumption. Relative currents and slope currents.

Module: IV

Currents with friction-Equation of motion with friction-Ekman's solution to wind driven flow-Ekman Spiral-Ekman transport - Ekman pumping – Upwelling and Sinking- Bottom friction and shallow water effects. Sverdrup's theory of ocean circulation-mass transport stream function- general form of Sverdrup's equation. Stommel's theory of western boundary currents- Munk's solution for wind driven circulation.

Module: IV

Vorticity-Relative Vorticity-Planetary Vorticity–-Potential Vorticity- Conservation of potential vorticity and its applications- westward intensification-Equatorial undercurrent. Ekman pumping-Taylor Proudman theorem- Rossby radius of deformation-Barotropic and baroclinic instability.

Reference

1. Pond and Pickard (1983): Introductory Dynamical Oceanography
2. Robert H. Stewart (2003): Introduction to Physical Oceanography- online edition (public domain).
3. Benoit Cushman-Roisin and Jean-Marie Beckers (2009): Introduction to Geophysical Fluid Dynamics. Physical and Numerical Aspects
4. Gill, A. E., (1982): Atmosphere-Ocean Dynamics
5. John A. Knauss (1997) Introduction to Physical Oceanography
6. Henk A. Dijkstra (2008) Dynamical Oceanography

OS-POC-503 Waves and Tides

Module: I

Introduction to Waves- Ocean wave classification - capillary and gravity waves – Wave generation- Sea and swell- Linear waves- wave dispersion- Phase and Group velocity- Classification of deep and shallow water waves.

Module: II

Finite amplitude waves- Stokes theory- Shallow water waves- Nonlinear waves- Cnoidal and Solitary waves- Wave transformations- shoaling, refraction, diffraction, reflection, wave run up, long-shore currents and rip currents. Orbital motions in deep and shallow water waves – Wave breaking – Types of wave barkers- Wave-height and period distributions- Rayleigh distribution- Wave statistics and wave spectra.

Module: III

Internal waves-two-layer ocean- normal modes of internal waves – causes of internal waves. Planetary Waves- Poincare, Rossby, Kelvin, and Yanai waves- Tsunamis- Seiches

Module: IV

Introduction and history of tides- tide Generating forces in ocean - lunar and solar components- types of tides- spring and neap tides- typical tidal ranges at coast, estuaries, bays and open ocean- tidal currents- internal tides - phase, amplitude and cycle time- amphidromic points- cotidal lines- tidal bores

Module: V

Tide generating forces- Newton's theory- Equilibrium theory - Dynamic theory- Observations and prediction of tides- Harmonic analysis

Reference:

1. Pond and Pickard :(1983) Introductory Dynamical Oceanography
2. Sverdrup H.U., Johnson M.W. and Fleming R.H: (1958) The Oceans: their physics, chemistry and general biology, Prentice Hall Inc., New Jersey.
3. Open University Course team and Butterworth-Heinemann (1999): Waves, Tides and Shallow Water Processes; Open University team, 2nd Edition, 1999, Oxford, UK
4. Philips O. M. (1966) The Dynamics of the upper ocean.
5. Pierson W. J., G. Neumann and R. W. James (1955) Practical methods for observing and forecasting Ocean waves.

Major: DSE

OS-POE-501 General Meteorology

Module: I

Introduction to Meteorology - Definition of Weather and Climate - Weather Elements- - Horizontal and Vertical distribution of air temperature and atmospheric pressure-Atmospheric Stability - Structure and composition of Atmosphere- Scales of weather systems – micro, meso, synoptic and planetary scales – Classification of Clouds.

Module: II

General circulation of the atmosphere – Hadley and Walker Circulation – Trade winds – ITCZ, Doldrums, Polar front – Coriolis Force- Geostrophic and Gradient winds – Jet Streams-Quasi Biennial Oscillations.

Module: III

Definition of monsoon- Monsoon regions of the World – Southwest (summer) and Northeast (winter) monsoons over India – Monsoon onset and withdrawal – Monsoon Trough – Active and Break monsoons – Monsoon depressions – Low level Jet – Factors affecting monsoon – Intra- seasonal Variability – Madden-Julian Oscillations- Monsoon and Indian Ocean.

Module: IV

Thunderstorms-Hailstorm-Tropical Cyclones – classification – T-number – Genesis, intensification, movement and landfall– vertical structure – Tropical Cyclones in Arabian Sea and Bay of Bengal. Extratropical cyclones – Anticyclones – Western disturbances – Airmass and Fronts – Squall- Tropical cyclones in the Bay of Bengal- blizzards- Dust storms- Norwesters.

Module: V

Fundamentals of Weather Forecasting- observation of weather elements-Preparation of surface weather maps- analysis and interpretation- different types of forecasting (general, statistical, numerical)- Special weather forecasting (agricultural, route forecasting, cyclone warning, etc.)

References

1. Battan L.J. (1979) Fundamentals of Meteorology, Prentice Hall Inc., N.J.
2. Donn W.L. (1975) Meteorology, McGraw Hill book company, New York.
3. Petterson S. (1969) Introduction to Meteorology, McGraw Hill book company, New York.
4. Monsoon (2- volumes) (2012) India Meteorological Department
5. James R. Holton (2004) An Introduction to Dynamic Meteorology. 4th edition
6. Seymour L. Hess (1959) Introduction to theoretical meteorology.
7. Chandrasekar A. (2010) Basics of Atmospheric Science.

OS-POE-502 Essentials of Biological Oceanography

Module: I

Introduction to Marine environment, History of marine biological investigations in India and major expeditions. Salient features of world oceans. Oceanographic features of Arabian Sea, Bay of Bengal and Andaman Sea. Divisions of the sea - Zonation in marine environments.

Physico-chemical features of Marine environment- tides, currents, waves, upwelling and monsoon cycles, Mud banks.

Module: II

Salient ecological features of coastal ecosystems-wetlands, estuaries, mangroves, sea grasses, coral reefs, rocky and sandy shores, and deep sea ecosystems. Continental shelf and seabed, Extreme environments – polar regions and hydrothermal vents.

Module: III

Marine living and non-living resources. Planktonic deposits and oozes in marine environment. Classification of marine organisms by habit and habitat.

Introduction to marine flora – microalgae, macroalgae, seagrass, salt marshes and mangroves and their distribution patterns in Indian EEZ. Systematic and general description of marine faunal groups. Indicator organisms, Plankton blooms, Toxic algae and its impact on fisheries.

Module: IV

Marine biodiversity, Conservation status, Endangered marine mammals and sea turtles, CITES, Red data list and its categories. Regulations concerned with conservation of the marine fauna and flora. Marine sanctuaries, Marine Protected Areas (MPAs), Large Marine Ecosystems (LMEs), etc. Regulations related to maritime boundaries, EEZ and territorial waters.

Module: V

Marine ecosystems and climate change - climate forcing on the marine ecosystem, human impact on marine ecosystem, socio-ecological aspects of global warming and sea-level rise. Marine ecosystem and marine resource management in the changing scenario.

References

1. Barbara, Charton. (2007). *The Facts on File Dictionary of Marine Science. (Facts on File Science Dictionary)*, Facts on File.

2. Charles B. Miller, Patricia A. Wheeler (2012). *Biological Oceanography* (2nd Edition). Wiley-Blackwell

3. Ewart,Newell.,& Newell, R.C. (2006). *Marine Planktons*. Facsimile Edition. Pisces Conservation Ltd.

4. George,Karleskint., Richard, Turner., & James, Small. (2012). *Lab Manual: Introduction to Marine Biology*(4thEdition). Brooks Cole.

5. Holme, N.A & Mc.Intyre, A.D. (1984). *Methods for the study of marine Biology*(2ndEdition). Blackwell Science.

6. James, W. Ngbkken., & Mark, D. Bertness. (2004). *Marine Biology: An Ecological Approach* (6thEdition). Benjamin Cummings.

7. Jeffrey S Levinton (2017). *Marine Biology- Function, Biodiversity, Ecology*, (5th edition), Oxford University Press..

8. John, Erickson. (2003). *Marine Geology: Exploring the New Frontiers of Ocean* (Revised Edition). Checkmark Books.

9. Krishna, N. Pillai. (1986). *Introduction to Planktonology* (1stEdition). Himalaya Publishing House.

10. Nair, N.B.,&Thampi, D.M. (1980). *Outlines of Marine Ecology*. Hindusthan Publishing Company.

11. Norman, B. Marshall. (1954).*Aspects of Deep Sea Biology*. Philosophical Library.

12. Omori, M & T. Ikeda (1992) *Methods in Marine Zooplankton Ecology* (1stEdition). Krieger Pub Co.

13. Peter Castro., & Michael, E. Hubsor. (2018). *Marine Biology* (11th Edition). McGraw-Hill Science/Engineering/Math

14. Russel, H.W.D. (1979). *A Life of Vertebrates* (1stEdition).Macmillian.

15. Seshappa, G. (1992). *Indian Marine Biology*. South Asia Books.

16. Sverdrup, H.U., Martin, W. Johnson., & Richard, H. Fleming.(1968).*The Oceans – Their Physical, Chemistry and General Biology*. Prentice Hall.

17. Tom, S. Garrison. (2009). *Oceanography: An invitation to Marine Science* (7thEdition). Brooks Cole.

Minor: Marine Chemistry

OS-MMC-501 Marine Geochemistry

Module: I

Fundamentals of geochemistry:

Geochemical classification of elements. Geochemistry of crust, mantle and core of the earth. Geochemical Cycle. Mobility of elements, Isomorphism, polymorphism and atomic substitution. Thermodynamics and chemical reactions.

Module: II

Isotope geochemistry:

Introduction to isotope geology, Isotopes, isobars and isotones, stable and radioactive isotopes. Radioactive decay schemes. Decay constant, half life, parent-daughter relations. Rb-Sr and Sm- Nd systematics and their use in geochemistry. Short-lived isotopes.

Module: III

Stable isotopes:

Processes of isotope fractionation, δ-notation for C, O, N and S isotopes, fractionation factor. Water isotopes – O, H fractionation in the hydrologic cycle and applications.

Module: IV

Marine sedimentary processes:

Sedimentary environments and facies; Weathering and transportation; Coastal and continental shelf sedimentation processes; Pelagic Sedimentation and sedimentary processes; Source to sink and processes governing their transport. Chemical sedimentation: authigenic mineralization and detrital clay minerals.

Module: V

Marine geochemical processes:

Nutrients, major, minor and trace elemental distribution in marine sediments; Carbon, nitrogen, phosphorus and sulphur cycling in marine sediments; Early diagenesis in marine sediments – dissolved constituents of sediment pore water, influence of bioturbation. Mineralizatione of oxygen and nitrate distribution in marine sediments; Nitrification and denitrification; Benthic fluxes, redox reactions. Reactivity of iron in marine sediments – pathways if iron input, iron as a limiting nutrient in oceans; early diagenesis; Sulphate reduction in marine sediments – biotic and abiotic processes; Hydrothermal processes and mineralization – black smokers and massive sulphide formation.

References:

1. Holland, H. D., and K. K. Turekian, eds. Treatise on Geochemistry. Elsevier Science, 2003.

2. Roy Chester and Tim. D. Jickells, Marine Geochemistry, Wiley-Blackwell, 3rd Edition, 2012.

3. H. D. Schulz and M. Zabel, Marine Geochemistry, Springer, 2nd Edition, 2006

4. Jochen Hoefs, Stable isotope geochemistry, Springer-Verlag, 1996, 2009.

5. Gunter Faure, Principles of Isotope Geology. J. Wiley & Sons, 2004.

6. Harry Elderfield, Heinrich D. Holland, Karl K. Turekian, The Oceans and Marine Geochemistry, Elsevier, 2006.

7. William M. White, Isotope Geochemistry, Wiley-Blackwell, 2015.

OS-MMC-502 Chemistry of Marine Natural Products

Module: I

Drugs and pharmaceuticals from Marine Sources

Introduction, Marine secondary metabolites and their function, Biosynthetic pathways of terpenes, sterols and phenolic compounds, Some major marine drugs – anticancer agents, antimicrobial and antiviral compounds, analgesics (examples only), Marine organisms having potential bioactive compounds – Corals, marine micro organisms, marine plants, marine toxins as drugs, Fish and shell fish. Marine drug developmet – problems and challenges.

Module: II

Seafood proteins

Nutritional value of seafood proteins, bioactive peptides, Isolation of seafood peptides- Functional value – Calcium binding, antibacterial and anti-oxidant activity. Marine enzymes – Isolation and applications, Anti-freeze proteins – applications, Cold adapted enzymes – applications.

Module: III

Seaweeds -Nutritional value, bioactive properties and uses

Proximate composition, seaweeds as dietary supplements, Seaweeds as sources of bioactive compounds – antioxidant, anti-bacterial and anti-viral activities, Industrial applications of seaweeds – agriculture, aqua culture feed, anti-fouling agents, biosorption of heavy metals. Seaweed hydrocolloids – Agar, alginate, carrageenan – structure, extraction, properties and biological activity.

Module: IV

Marine Macromolecules as Nutraceutical Carriers and Biofilm

Matrix design for delivery of nutraceuticals, Marine macromolecules as delivery system, Biodegradable and edible films, Marine macro molecules as food coatings and edible films – marine proteins and marine polysaccharides, Nanotechnology for marine polysaccharide films and particles, Marine macromolecules as hydrogels and membrane for drug delivery, marine polysaccharides as Scaffolds.

Module: V

Isolation Techniques

Introduction, different extraction methods, purification by solvent extraction, chromatographic techniques (size exclusion, ion exchange, counter current), Idea about different spectroscopic techniques.

Practicals: Isolation of natural products from different marine plants. Identification using modern Analytical techniques.

References

1. Chemistry of marine natural products. Paul J Scheuer, 1973. Academic Press.

2. Handbook of Marine natural products. Fatturosso, Emesto, Gerwick, William H, Taglialatela Scafati, Orazio (Eds.) 2012. Springer.

3. Bioactive marine natural products. Bhakuni, Dewari S and Rawat P.S . 2005.

4. Handbook of Marine Biotechnology, S K Kim, 2015. Springer.

5. Marine products for health care. Functional and Bioactive nutraceutical compounds from the ocean. Vazhiyil Venugopal. CRC Press. 2009.

6. Seigler, D.S. (1998). Introduction to Terpenes. In: Plant Secondary Metabolism. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-4913-0_18

7. W. David Nes, 2011. Biosynthesis of Cholesterol and Other Sterols Chemical Reviews 111 (10), 6423-6451 DOI: 10.1021/cr200021m

8. W. Vermerris and R. Nicholson 2006, Phenolic Compound Biochemistry Springer https://doi.org/10.1007/978-1-4020-5164-7

Minor: Marine Biology

IMB5-MB-DSC10-201 Marine Ecological Dynamics and Marine Environment Assessment

Module: I

Marine Ecosystem Dynamics

Structure and functioning of marine ecosystems; ecological interactions in marine food webs; trophic dynamics; energy flow and ecological efficiency; ecological succession in marine habitats; population and community dynamics; ecosystem stability and resilience; carrying capacity in marine ecosystems.

Module: II

Coastal and Oceanic Ecosystem Processes

Ecological dynamics in estuaries, mangroves, coral reefs and seagrass ecosystems; nutrient cycling and productivity; benthic-pelagic coupling; microbial interactions in marine systems;

seasonal and spatial variability in marine ecosystems; ocean-atmosphere interactions influencing ecosystem dynamics.

Module: III

Marine Environmental Assessment Methods

Principles of environmental assessment; environmental indicators and bioindicators; biodiversity assessment methods; ecological sampling techniques; water and sediment quality assessment; habitat mapping and ecological monitoring; environmental impact assessment in marine systems; environmental baseline studies.

Module: IV

Marine Environmental Changes and Ecosystem Responses

Natural and anthropogenic disturbances in marine ecosystems; eutrophication and habitat degradation; invasive species impacts; climate variability and ecosystem responses; coral bleaching and habitat shifts; ecological restoration and rehabilitation approaches.

Module: V

Applied Marine Ecology and Sustainable Management

Integrated coastal zone management; ecosystem-based fisheries management; marine protected areas; blue carbon ecosystems; remote sensing and GIS applications in marine environmental assessment; conservation planning; sustainable marine resource management.

Practicals

Assessment of biodiversity indices; ecological sampling methods; plankton and benthos analysis; estimation of ecological parameters; water and sediment quality analysis; habitat mapping exercises; preparation of environmental impact reports; field visits to estuarine or coastal ecosystems.

References

1. Kaiser, M. J. et al. Marine Ecology: Processes, Systems, and Impacts. Oxford University Press.

2. Lalli, C. M. & Parsons, T. R. Biological Oceanography: An Introduction. Butterworth-Heinemann.

3. Castro, P. & Huber, M. E. Marine Biology. McGraw-Hill Education.

4. National Centre for Sustainable Coastal Management coastal management and environmental assessment manuals.

5. Central Marine Fisheries Research Institute ecosystem assessment and coastal ecology publications.

(IMB5-MB-DSC13-320 Genomics, Proteomics and Molecular Genetics

Module: I

Molecular Genetics and Genome Organization

DNA structure and replication; gene organization; chromosomes and genome architecture; transcription and translation; regulation of gene expression; mutations and DNA repair mechanisms.

Module: II

Genomics and Genome Analysis

Genome sequencing methods; structural and functional genomics; comparative genomics; metagenomics; genome annotation; molecular markers and DNA barcoding; genome databases and bioinformatics tools.

Module: III

Proteomics and Protein Analysis

Protein structure and folding; proteome organization; protein separation methods; electrophoresis and chromatography; mass spectrometry basics; protein-protein interactions; functional proteomics and biomarker discovery.

Module: IV

Molecular Biotechnology and Omics Applications

Recombinant DNA technology; CRISPR and gene editing basics; transcriptomics and metabolomics; molecular diagnostics; marine biotechnology applications; genomics in aquaculture and fisheries; environmental genomics.

Module: V

Ethical, Environmental and Applied Perspectives

Ethical issues in genomics and biotechnology; biosafety and biosecurity; genetic conservation; molecular approaches in biodiversity conservation; personalized medicine concepts; future trends in omics sciences and marine biotechnology.

Practicals

DNA and RNA extraction; PCR demonstrations; gel electrophoresis; protein estimation methods; bioinformatics database exercises; sequence analysis; molecular marker analysis; preparation of molecular biology reports.

References

1. Watson, J. D. et al. Molecular Biology of the Gene. Pearson.

2. Lesk, A. Introduction to Genomics. Oxford University Press.

3. Twyman, R. Principles of Proteomics. BIOS Scientific Publishers.

4. Walker, J. M. & Rapley, R. Molecular Biology and Biotechnology. Royal Society of Chemistry, Indian Edition.

5. National Institute of Biomedical Genomics genomics and molecular biology publications.

SEC (Skil Enhancement Courses)

OS -SEC-501 Computer Applications in Oceanography

Module: I

Plotting of Vertical sections of temperature, salinity and density data and Interpretation of oceanographic features.

Module: II

Preparation of horizontal sections of physical properties and Chlorophyll. Computations of specific volume anomalies and potential temperature from sample data Sets.

Module: III

Computations of geostrophic currents using hydrography data or sea level anomaly data.

Module: IV

Stability Analysis. Estimation vertical velocity. Estimation of Ekman current and Ekman Spiral.

Module: V

Wave data analysis

Semester VI

Major: DSC

OS-POC-601 Air Sea Interaction

Module: I

Air-sea interaction: Atmospheric boundary layer- fluxes of mass, momentum and heat -- wind stress - wind stress curl - friction velocity - eddy viscosity- Reynolds's Number - turbulence-

characteristics of turbulent flow - scales of air-sea interaction Kolmogorov length scale - Taylor's micro scales.

Module: II

Wind profile in the atmospheric boundary layer - mixing length - effect of stability on wind profile -turbulent transport of fluxes - Von Karman Constant - Modelling the atmospheric boundary layer-turbulence closure - K-theory - Prandtl's mixing length theory - Reynolds stress equation model - Monin-Obhukov length - Monin-Obhukov surface layer similarity theory for stratified atmosphere **-** air-sea interaction in coastal zone - sea and land breeze.

Module: III

Estimation and measurement of fluxes - eddy correlation method - bulk aerodynamic method- Fluxes from Satellite observations and ocean weather stations - measurement of surface fluxes from ocean weather stations.

Module: IV

Heat budget of the ocean - Short wave and long wave heat fluxes - albedo -factors affecting short wave and long wave heat fluxes - sensible and latent heat flux - net heat flux- Bowen's ratio - annual cycle of heat fluxes - spatial and time variation of heat fluxes - meridional heat transport in the ocean.

Module: V

Role of Oceans in climate - Large scale air-sea interaction processes - El Nino and La Nina-Southern Oscillation - El Nino-Modoki, - North Atlantic Oscillation - Atlantic Multi-decadal Oscillation – Pacific Decadal Oscillation -Arctic Oscillation - Antarctic Oscillation –Indian Ocean Basin Mode (IOBM) - Indian Ocean Dipole (IOD).

Reference:

1. Kraus, E. B. and J. A. Businger Atmosphere - Ocean Interaction, 2nd edition.
2. G T Csanady, Air-sea interaction: laws and mechanisms
3. Y. Toba (2004) Ocean-Atmosphere interactions
4. John Marshall and Alan Plumb (2007) Atmosphere, Ocean and climate Dynamics – An introductory text.
5. Adrian E. Gill (1982) Atmosphere-Ocean Dynamics
6. Neil Wells (1986) The atmosphere and Ocean – A physical Introduction

OS-POC-602 Coastal and Estuarine Processes

Module: I

Coastal Geomorphology- Evolution of the coast in relation to sea level changes- Geomorphology of the coast-Shelf geological processes- Beach Definition, beach and surf zone morphology- Coastal Land forms- Depositional and Erosional environments- Mud banks- coastal erosion and accretion -Natural and anthropogenic - Coastal Protection methods.

Module: II

Classification of Estuaries- Circulation, mixing and stratification- Flocculation-Tidal asymmetry and flushing- Estuarine sedimentation-Tidal Prism- Tidal inlets and creeks-Mangroves-Delta- Intertidal zone-Tidal Flats-Salt marshes-Estuaries in Kerala.

Module: III

Coastal Oceanography- Shallow water wave transformation-wave shoaling - Wave breakers-Wave decay in surf zone- Infra Gravity waves- Edge waves- Littoral currents- Cross shore, long- shore and rip currents- coastal flooding-Kallakadal- tidal currents- sediment transport-Aeolian and littoral transport- Classification of sediments- Grain size analysis

Module: IV

Shoreline Changes- Beaches- Beach Cusps- Edge waves and rhythmic formations- beach profiles- Profile changes due to storms-Long-shore bars and troughs- barriers and barrier Islands- Classification of beaches- Beach processes – source, nature and character of the beach material- beach stability- Coastal response to Engineering structures- Remote sensing for shoreline mapping

References:

1. Paul D Komer (1997) Beach Processes and Sedimentation, Prentice Hall, 2nd Edition
2. Pethick J, (1984) An Introduction to Coastal Geomorphology (Arnold)
3. Horikawa, K. (1978). Coastal Engineering (University of Tokyo Press)
4. Dean, R G and Darlymple, R A, (2001). Coastal Processes with Engineering Applications (Cambridge University Press)
5. J.S. Mani (2012) Coastal Hydrodynamics
6. Dyer K.R (1973) Estuaries: A Physical Introduction, John Wiley
7. Dyer K.R (1986) Coastal and Estuarine Sediment Dynamics; In : Coastal and Estuarine Sediment Dynamics, John Wiley & Sons Ltd
8. CAM King (1961) Beaches and Coasts
9. U S Army CERC, (1984 or latest). Shore Protection Manual

OS-POC-603 Oceanographic Instruments

Module: I

Ocean Observation Platforms- Ship-based Measurements- Oceanographic Data collection-Spatial and Time-series stations- Winches, wire ropes, messengers- Nansen water bottles and Reversing thermometers- Collection of salinity and oxygen samples- Thermo-salinograph-Autosal and salinity calibration- SST bucket thermometer- Seichi disk and Radio meter - Mechanical Bathy Thermograph (MBT) and Expendable Bathy Thermograph (XBT) system-

Conductivity, Temperature and Depth (CTD) with Rosette sampler- XCTD - Automatic Weather Station (AWS)

Module: II

Current measurements- Eulerian and Lagrangian methods- Swallow Floats- Types of Current meters- Propeller and Acoustic Devices- Speed and Direction measurements- Mooring of Current meters- Shallow and Deep water moorings- Acoustic Doppler Current Profilers (ADCP)- Ship hull mounted and bottom mounted ADCP systems.

Module: III

Wave Measuring Devices- Bottom mounted pressure sensors- Ship-Borne Wave Recorder (SBWR) systems (Tucker's device)- Accelerometer and pressure sensors- Waverider Buoys- Directional Wave buoys- Tide Staff and Tide Gauges- Acoustic Tide Gauges- Mooring of Wave buoys and Tide sensors- Coastal and ship-borne Radars for measuring waves.

Module: IV

Argo floats and Gliders for Oceanographic data collection- Towed Oceanographic Data Collection systems and AUVs- AXBT systems- Meteorological Instruments- Echosounder

References:

1. Pickard G.L. and W.J. Emery (1995): Descriptive Physical Oceanography- Pergamon press.
2. Sverdrup H.U., Johnson M.W. and Fleming R.H- The Oceans: their physics, chemistry and general biology, Prentice Hall Inc., New Jersey, 1958.
3. William J. Emery and R. E. Thomson (2001): Data Analysis and methods in Physical Oceanography, Elsevier

Major: DSE

OS-POE-601 Marine Geology

Module: I

Ocean floor topography – Shelf, slope, rise, abyssal plains, submarine canyons, mid oceanic ridges, plateaus, sea minerals, sea mounts, guyots, fracture zones, trenches. Seafloor spreading – concepts, hypothesis and mechanisms, evidences of seafloor spreading. Plate tectonics – theories and concepts, major plates and plate motions. Mountain building activity – concepts and hypothesis.

Module: II

Evolution of oceans – Submarine volcanism, rift system, origin and ages of ocean basins. Active and passive continental margins. Structure and evolution of Pacific, Atlantic and Indian Oceans, Red sea and Mediterranean sea. Sea level changes – causative factors and types of sea level changes; methods of study of sea levels and their changes.

Module: III

Oceanic sediments – Processes and patterns of sedimentation; turbidity and density currents and their role in marine sedimentation. Sediment distribution in different oceanic regions; distribution in the Arabian Sea and Bay of Bengal. Physical and geotechnical properties – porosity, permeability, bulk density, vane shear and compressibility. Gas charged sediments- special reference to North Indian Ocean.

Module: IV

Marine mineral resources – Beach and nearshore placer deposits. Polymetallic nodules, Sulfides, cobalt rich crusts – genesis, occurrence, distribution, mineralogy and chemistry. Phosphirites – Genesis, occurrence and distribution. Mineral resources of the Indian ocean. Offshore oil and gas – Genesis, accumulation and preservation. Offshore oil and gas fields of India.

Module: V

Samplers – Grabs, Corers, Dredges. Exploration and Mining techniques of Marine Mineral Resources. Prospects of ocean mining; Environmental aspects of ocean mining.

Reference:

1. Marine Geology J. Kennet
2. Geotectonics Belonssov V.V.
3. Plate tectonics and crustal evolution Condia K.C.
4. The Geology of Continental margins C.A. Burk & C.L. Drake
5. Sea levels, land levels and tide ganges Emery & Aubrey
6. Marine Manganese nodules Wallace

OS-POE-602 Marine Bio-Geochemical Processes

Module: I

Major ocean biogeochemical cycles – carbon, nitrogen, silicon and phosphorus cycles, micro-nutrient dynamics and cycling- Organic matter- dissolved, particulate and colloidal species, sources, classification, composition, distribution, seasonal variations- Ecological significance- Growth promoting and growth inhibiting effects- Biogeochemical cycles.

Module: II

Phytoplankton and primary productivity - pigments, photosynthesis – net and gross primary productivity- rate of primary production in inshore and offshore regions of Arabian Sea and Bay of Bengal- Latitudinal and Seasonal variations in primary productivity- Factors affecting primary production, methods of estimation- Relationship of phytoplankton productivity to light and nutrients- Role of phytoplankton in global carbon cycle – Impacts of climate change- Algal blooms – HABs and TABs- Ocean Colour Monitoring and estimation of primary productivity.

Module: III

Influence of Physical processes on primary productivity- Hydrodynamic forcing- Upwelling, stratification, mixed layer depth, turbulent mixing, monsoon driven biogeochemical processes in the Arabian Sea and Bay of Bengal – Spatial and Temporal variations in the nutrient concentrations- Response of marine pelagic ecosystems to climatic forcing, OMZ, HNLC- Ocean currents and their impact on marine life- Phytoplankton distribution ad patchiness.

Module: IV

Zooplankton communities in estuarine, neritic and oceanic systems. Secondary production- Linkages to higher trophic level, Plankton as indicators of fisheries. Indicator species of water masses. Benthic ecosystem processes, benthic environment and community structure,

Organism sediment relations. Benthic pelagic coupling, CDOM.

Module: V

Plankton in relation to fisheries –Plankton as indicators of fisheries- Potential Fishery Zones- SST variations and pelagic fisheries- Influence of upwelling on oil sardine fishery in Arabian Sea, Larval transport and recruitment- Effects of climate change on Coastal upwelling systems- Fish migrations.

Reference:

1. John H Simpson and Jonathan Sharples (2012): Introduction to the Physical and Biological Oceanography of Shelf Seas; Cambridge University Press.
2. Tom Beer (1996): Environmental oceanography (CRC Marine Science), 2nd Edition, CRC Press
3. J P Riley & Chester Introduction to Marine Chemistry. Academic Press London and New York
5 Biological Oceanography an Introduction. Carol M. Lalli& Timothy R. Parsons. Elsevier, Butterworth-Heinemann Marine biology. Peter Castro & Michel E Huber. The Mc-Graw companies.

Minor -**Marine Chemistry**

OS-MMC-601 Instrumental Methods in Marine Chemistry

Module: I

Electroanalytical Techniques

Voltammetry; Coulometry; Amperometry; Potentiometry; Polarography; Electrolytic conductivity.

Module: II

Spectrophotometry

Fundamental laws of photometry, interference and photometric error, instrumentation of photometers. Flame Spectrophotometry – Flame emission spectrometry, Atomic absorption Spectrophotometry – general principles and instrumentation, interferences, Cold vapour techniques for estimation of Mercury, metal hydride generation techniques, electro thermal atomisation. Atomic fluorescence spectrometry, Inductively coupled Plasma analysis. Basic instrumentation for UV-Vis, IR and Fluorescence spectrophotometers.

Module: III

Chromatographic Techniques

Classification of chromatographic techniques. Experimental techniques and applications of Ion-exchange, Column, Thin Layer and Paper chromatography. HPLC and Gas Chromatography Principle, Instrumentation and Detectors. Methods and applications.

Module: IV

NMR Spectrometry

NMR – Basic Principles and Instrumentation of Continuous Wave and Pulsed Fourier Transform NMR Spectrophotometers.

Module: V

Mass Spectrometry

Mass Spectrometry – Basic Principles, Instrumentation – Sample flow, Ionisation methods, mass analysers, Ion collecting systems, Analysis of data, Fourier Transform Mass Spectrometry, MS-MS, ICP-MS, SIMS, IMMA.

Practicals: Data analysis and interpretation using NMR, UV-VIS, FTIR & Mass Spectoscopy.

References

1. J.M. Mermet, M.Otto, R.Kellner , Analytical Chemistry, Wiley –VCH, 2004.
2. D.A. Skoog, D.M. West, F.J.Holler, S.R. Crouch, Fundamentals of Analytical Chemistry, 8thEdn, Saunders College Pub, 2007.
3. G.D. Christian, J.E. O'Reilly, Instrumental Analysis, Allyn and Bacon, 1986.
4. J.H. Kennedy, Analytical Chemistry: Principles, Saunders College Pub 1990.
5. J.G. Dick, Analytical Chemistry, R.E. Krieger Pub., 1978.

Minor: Marine Biology

IMB6-MB-DSC14-310 Deep Sea Ecology and Biodiversity

Module: I

Introduction to Deep Sea Environment

Definition and extent of deep sea; history of deep-sea exploration; bathymetric zones of oceans; physical characteristics of deep-sea including pressure, temperature, light and salinity; deep ocean circulation; geological features of deep oceans; trenches, abyssal plains and hydrothermal vents.

Module: II

Deep Sea Biodiversity

Diversity of deep-sea microorganisms; deep sea invertebrates and vertebrates; benthic and pelagic deep-sea fauna; adaptations to deep sea conditions; bioluminescence; gigantism and dwarfism; trophic interactions in deep sea ecosystems; chemosynthetic communities. Deep sea bioresources and fishery resources.

Module: III

Deep Sea Ecosystem Processes

Deep sea food webs and nutrient cycling; marine snow and organic matter deposition; microbial ecology in deep oceans; hydrothermal vent ecosystems; cold seep ecosystems; deep sea carbon cycling; ecological connectivity between deep and shallow marine systems.

Module: IV

Deep Ocean Exploration and Technology

Deep sea sampling methods; submersibles and remotely operated vehicles; deep sea sensors and observatories; ocean mapping techniques; Deep Ocean Mission of India; polymetallic nodules and marine mineral resources; deep sea biotechnology prospects.

Module: V

Conservation and Sustainable Management

Threats to deep sea ecosystems; deep sea mining impacts; marine litter and pollution in deep oceans; climate change impacts on deep sea systems; legal and ethical issues in deep sea resource utilization; conservation of deep ocean biodiversity; international governance of deep-sea resources.

Practicals

Identification of deep-sea organisms from images and collections; analysis of bathymetric maps; deep sea biodiversity database exercises; interpretation of oceanographic datasets; sediment analysis demonstrations; preparation of deep-sea ecosystem reports.

References

1. Gage, J. D. & Tyler, P. A. Deep-Sea Biology: A Natural History of Organisms at the Deep-Sea Floor. Cambridge University Press.

2. Castro, P. & Huber, M. E. Marine Biology. McGraw-Hill Education.

3. Smith, C. R. & Branch, T. A. Deep-Sea Ecology. Oxford University Press.

4. National Institute of Ocean Technology Deep Ocean Mission publications.

5. National Centre for Polar and Ocean Research deep sea and polar marine ecosystem publications.

SEC

OS-SEC-601 Oceanographic & Meteorological Data Analysis

Module: I

Standard Oceanographic data analysis and interpretation of results. Vertical and horizontal sections of temperature salinity density and other properties

Module: II

Hovmoller diagrams and interpretation**.** Time series analysis of data

Module: III

FFT and wavelet analysis**.** Low pass and high pass filters**.** EOF analysis and interpretation**.** Wave data analysis.

Module: IV

Plotting of different weather parameters on a weather chart. Synoptic analysis and Interpretation of weather parameters. Analysis of cyclonic and anti-cyclonic conditions for some typical weather scenarios

VAC (Value Added Courses)

OS-VAC-601 Sedimentary Geochemistry Diagnostics Techniques

1. Sampling of sediment (surficial and subsurface)
2. Storage and preservation of water and sediment samples for environmental analysis.
3. Determination of pH & Eh
4. Determination of pigments (Chlorophyll a, b, c and phaeopigments).
5. Determination of sediment texture, organic carbon, total nitrogen and total Sulphur.
6. Determination of trace metal from sediment samples.
7. Determination of POP in surficial and subsurface sediment samples.
8. Determination of Microplastics from surficial sediment samples.

Reference

1. IOC Manuals and Guides-12. Chemical Methods for use in Marine Environmental Monitoring, UNESCO. 1983

OS-VAC-602 Fundamentals of R Programming

Module: I

Introduction to R Programming

Introduction to R and RStudio - R environment and scripting - Variables, data types, and operators - Basic programming syntax

Module: II

Data Structures and Data Handling

Vectors, matrices, arrays - Lists and data frames – Factors - Importing datasets - Data indexing and manipulation

Module: III

Control Structures and Functions

Conditional statements - Loops in R - User-defined functions - Apply family functions

Module: IV

Statistical Analysis Using R

Descriptive statistics - Correlation and regression - Hypothesis testing basics - Time series basics. Data interpretation

Module: V

Data Visualizations in R

Base graphics in R - Histograms, boxplots, scatter plots -Line graphs and bar charts - Introduction to ggplot2

References:

1. Cirillo, A., 2016. Rstudio for R statistical computing cookbook. Packt Publishing.
2. Kuhnert, P., Venables, B. and Zocchi, S.S., 2005. An introduction to R: software for statistical modelling & computing (p. 50p). USP/ESALQ/LCE.
3. Wenables, W.N. and Smith, D.M., 2021. An Introduction to R: Notes on R: a Programming Environment for Data Analysis and Graphics. Wirtschaftsuniversitat. Department of statistics and mathematics.

Semester VII

Major: DSC

OS-POC-701 Ocean Modelling

Module: I

Introduction to Ocean Modelling- Mechanistic and Simulation models- Conservation of Mass and Momentum – Navier-Stokes equations and Ocean circulation modelling- Spherical coordinates - Conservation of angular momentum – Conservation of Mechanical Energy- Global Ocean Modelling- Hydrostatic Primitive Equations- Initial and Kinematic Boundary conditions- Shallow water equations- Geostrophic adjustment- Quasi-geostrophy.

Module: II

Numerical Schemes- Finite Differences- Forward, Backward and Central differences- Explicit and Implicit schemes. Horizontal and vertical grid types-finite difference and finite element methods- lateral boundary conditions-bathymetry- Model forcing - Model Initialization and Spin up -ocean data assimilation-Time Differencing- Time Splitting.

Module: III

Barotropic and Reduced gravity models. Basin scale models and Regional models- Cox's Model of Indian Ocean- O'Brien's model of North Pacific Ocean- Holland and Hirschman's Model of Atlantic Ocean - 3 Dimensional Ocean Models- GFDL Modular Ocean Model (MOM)- Princeton Ocean Model (POM)- ROMS and HYCOM.

Module: VI

Introduction to wave modelling- Kelvin-Helmholtz, Jeffrey's, Sverdrup-Munk, Phillips' and Miles wave generation theories- Non-linear wave-wave interactions and wave growth- Early wave prediction methods- Significant wave and wave spectrum approaches- 1D and 2D wave spectrum- Sverdrup-Munk- Bretschneider (SMB) and Pierson-Neumann-James (PNJ) methods of wave prediction.

Module: V

Over view on numerical wave modelling- Evolution of spectral wave models- 1st, 2nd and 3rd generation wave models- Discrete spectral wave models- Parametric and Hybrid wave models- Coupled discrete wave models- Deep and shallow water wave models-Source functions and examples of models of 1st and 2nd generations -DSA, MRI, VENICE, PTB, SOWM, GSOWM, GONO, TOHOKU, HYPA, SAIL. Third generation wave model (3G WAM) - Wave Watch III model- SWAN model- Operational wave models- Cold start and

spin-up time of wave models- Data Assimilation techniques -Validation and inter-comparisons of models- Limitations of operational models.

Reference:

1. SWAMP Group 1985: Ocean Wave Modelling, Plenum Press, (pp.256).
2. M.L. Khandekar: Operational Analysis and Prediction of Ocean Wind Waves, Springer-Verlag, 1989.
3. Leo H. Holthuijsen (2010) Waves in Oceanic and Coastal Waters
4. Stanislaw R. Massel (1996) Ocean Surface Waves: Their Physics and Prediction
5. G. J. Komen, L. Cavaleri, M. Donelan (1994) Dynamics and Modelling of Ocean Waves
6. D.B. Haidvogel and A. Beckmann (1999) Numerical Ocean Circulation Modeling (Vol.2), Imperial College Press.
7. James J Obrien (1985) Advanced physical oceanographic numerical modeling (Nano science series).
8. Pond and Pickard (2013) Introductory Dynamical Oceanography, Butterworth-Heinemann
9. Kantha&Clayson: (2000) Numerical Models of Oceans and Oceanic Processes, Academic Press
10. Benoit Cushman-Roisin and Jean-Marie Beckers: (2009) Introduction to Geophysical Fluid Dynamics. Physical and Numerical Aspects
11. P. Muller H. von Storch (2004) Computer Modelling in Atmospheric and Oceanic Sciences

OS-POC-702 Ocean State Forecasting

Module: I

Potential fishing zone advisories and validation - Traditional methods of locating the fishing grounds- fish shoal based on their colour, behaviour and schooling patterns- Ariel surveys to locate the fishing grounds. Visual fish spotting from aircraft - Indirect detection by observing the associated sea surface.

Module: II

Remote sensing of sea surface parameters - Chlorophyll – biological productivity - SST - thermal fronts, Eddies, meanders, upwelling, rings, filaments, etc. - Cost benefits, reduction in search time and fuel - Ocean Tuna fishing advisories

Module: III

Ocean State Forecast - Numerical Models SST - Wave height and direction forecasts - Wave forecast for coastal states - Ocean State Forecast – ocean currents and temperature - Mixed layer and thermocline - Wind Speed and Direction- High wave alerts and Tsunamis warning- Forecasts along ship route- Cyclones and Storm surge forecasts.

Module: IV

Ocean Data Assimilation and Forecasting- Validation of ocean circulation and marine ecosystem models- Advanced data assimilation methods

Module: V

Satellites for Operational Oceanography- Global Ocean Observing System (GOOS) and Operational oceanography- Passive & active Techniques- Retrieval of Geophysical Parameters- Microwave Radiometers, Altimetry, High Level Data Processing and Products

References:

1. Eric P. Chassignet and Jacques Verron (2006) Ocean Weather Forecasting: An Integrated View of Oceanography
2. MischaelHord, "Remote Sensing Methods and Applications", John Wiley & Sons, New York, 1986.
3. Motoyoshi Ikeda and Frederic W. Dobson (1995). Oceanographic Applications of Remote Sensing, CRC Press, USA
4. Peter Michael Inness and Steve Dorling (1988) Operational Weather Forecasting
5. Kenneth E. Lilly (1981)An Introduction to Sea State Forecasting

DSE

OS-POE-701 Oceans and Climate

Module: I

Weather and Climate - Natural factors affecting climate - Milankovich cycles-other natural factors affecting climate change

Module: II

Paleo climate - Methods to study Paleo climate - Ice ages - Bond cycle - Abrupt climate changes- Dansgaard-Oescheger events - Heinrich events

Module: III

Effects of ocean on climate - formation and spreading of deep water masses in the ocean – Deep water circulation - meridional heat transport - ocean circulation and climate - Gulf Stream - effect of breakdown of thermohaline circulation on climate.

Module: IV

Anthropogenic causes of climate change - green-house effect - green-house gases - global warming - Recent changes in temperature over atmosphere and ocean. Projected changes in earth's temperature. Effects of global warming - weather and climate - sea level changes – Ozone Hole-Biological effects – Effect on agriculture- Ocean Acidification- Oxygen depletion-Role of ocean in global carbon cycle.

Module: V

Climate mitigation and adaptation – green technologies-reduction in emissions-increasing green cover- sustainable agriculture-renewable energy- Climate change policies-IPCC-International treaties/Protocols- Indian Climate change policies and planning.

Reference:

1. Dorothée Herr and Grantly R. Galland (2009): The Ocean and Climate Change
2. Dan Seidov, Bernd J. Haupt, Mark Maslin (2013) The Oceans and Rapid Climate Change:

Past, Present, and Future
3. Gerold Siedler, Stephen M. Griffies, John Gould and John A. Church (Eds.) (2001) Ocean Circulation and Climate_a 21st Century Perspective
4. Climate Change 2001 : Synthesis Report – IPCC, 2002
5. E Bryant (1997) Climate Process and Change
6. K KJurekian (1996) Global Environmental Change – Past, Present and future
7. Grant R. Bigg (2004) The Oceans and Climate.

OS-POE-702 Coastal Hazards and Management

Module: I

Coastal Hazards-Geological, oceanographic meteorological and anthropogenic hazards-Storms and storm surges-factors affecting storm surges-Tsunami-Causes-Tsunami transformation in shallow water-Case studies of most destructive Tsunami-Extreme waves - Coastal Flooding- Kallakadal -Rip currents.

Module: II

Coastal erosion-natural and man-made factors inducing coastal erosion- man made factors inducing coastal erosion-sediment budget-shoreline management plan-strategies for shoreline management-sediment cell-hard and soft solutions for coastal protection-sea level rise-causes and implications

Module: III

Marine pollution-classes of pollutants-trace elements and other inorganic chemicals-Acidity and Alkalinity-sewage and effluent pollution-ocean acidification-oil spills-Biological Disasters- Harmful algal blooms-Coral bleaching-effects of global warming on ocean food chain-man made coastal hazards.

Module: IV

Cases of hazards in Indian Coasts-Coastal Disaster Risk Management (DRM) – Hazard monitoring and evaluation- Coastal hazard risk reduction-Establishment of Early Warning System (EWS) for DRM- Indigenous Knowledge Systems for EWS-Institutional and legal arrangements for disaster risk management-Integrated Coastal Zone Management (ICZM) - Local and International constraints/challenges of ICZM- Policy, legislation and institutional framework- Environmental Impact Assessment

Reference:

1. Clark J R (1996) Coastal Zone Management Handbook (CRC Press (Lewis Publishers))
2. Klay R and Alder J(2005) Coastal Planning and Management (Taylor and Francis)2nd Edition
3. Shroder J F, Ellis T J and Sherman D J (editors)(2015) Coastal and Marine hazards, risks and disasters.

4. Van Dam J C (editor) (2005) Impacts of climate change and climate variability on Hydrological regimes (Cambridge University Press)
5. Houghton J(2009) Global warming – the complete briefing (second edition) (Cambridge University Press) IPCC 4th and 5th Reports

Minor - Marine Chemistry

OS-MMC-701 Atmospheric Chemistry

Module I

Introduction

Gas laws and properties, black body radiation and radiation laws -Atmospheric Composition and Structure: Chemical composition of earth's atmosphere Major and minor constituents, Vertical structure, Lifetimes, radiation balance – Carbon, Oxygen, Nitrogen and Sulphur cycles. of the Atmosphere – temperature regulation in the thermosphere, stratosphere and troposphere. Radiation balance and Green house effect, global warming- climate past and future.

Module: II

Fundamentals of Atmospheric Chemistry

Biogeochemical cycles of Carbon, Oxygen, Nitrogen and Sulphur cycles, halogen and trace element cycles- Photochemical processes – photo dissociation and ionisation, Reactions of electronically excited species, Chemical kinetics – Unimolecular, bimolecular, and termolecular reactions. Condensed-phase, surface and heterogeneous reactions.

Module: III

Atmospheric Aerosols

Sources, sinks and physical and chemical properties, Formation, growth and transformations of aerosols, Aerosol-cloud interactions, Stratospheric Aerosols, Aerosol climate feedbacks

Module: IV

Stratospheric Chemistry

Chapman model, Hox, Nox, CIox cycles, chemical mechanisms of polar ozone depletion, Anthropogenic impacts: Oxygen only chemistry, reaction scheme, Chapman layers. Influence of trace constituents – catalytic cycles, Null cycles, holding cycles and reservoirs, natural

sources and sinks of catalytic species. Heterogeneous and homogenous chemistry. Consequences of ozone perturbation, ozone variations and trends.

Practicals: 1. Sample collection and analysis of black carbon. 2. Aerosol sample collection and analysis for trace metals. 3. Air sample collections and analysis for green house gases.

References

1. R.P. Wayne. Chemistry of Atmospheres, Oxford University Press (2000)

2. P.V. Hobes. Introduction to Atmospheric Chemistry, Cambridge University Press (1999)

3. Nigel Bunce Environmental Chemistry, Wuerz Publishing Ltd. (1991).

4. Jacob, Daniel. Introduction to Atmospheric Chemistry . Princeton University Press, 1999

5. Seinfeld J.H and Pandis S.N, Atmospheric Chemistry and Physics ,2ndEd.,John Wiley and Sons,Inc.,2006

OS-MMC-702 Environmental Impact Assessment

Module: I

EIA Introductory Concepts:

Introduction to Environmental planning EIA process: evaluation of proposed actions: scoping EIA methodologies Impact Assessment Methodologies: Measurement of environmental impact, EIA Models, role of GIS in EIA base line study.

Module: II

Generalized approach to impact analysis:

EIA guidelines 2006, Notification of Government of India Procedure for reviewing Environmental impact analysis and statement. Baseline information and predictions (land, water, atmosphere, energy etc.). Concept and strategies of sustainable development, Cost-Benefit analysis, Environmental priorities in India and sustainable development.

Module: III

EIA Audits

Guidelines for Environmental audit: Definitions and concepts, partial audit, compliance audit, methodologies and regulations, 1SO14000, Consumption audits, pollution audits, hazardous issues and its voluntary audits.

Module: IV

EIA Case studies:

River valley projects: thermal power plants: mining projects: oil refineries and petrochemicals: tourism coastal zone development, EIA Regulations in India.

Module: V

Coastal Regulation Zone (CRZ):

Coastal Regulation Zone (CRZ) Notification, 2011,
Island Protection Zone (IPZ) Notification, 2011, Importance of CRZ Notification, Objectives, Limit of the CRZ Area, Allowed and not allowed activities in Coastal Zones, ICZMP.

References

1. John Glasson, Riki Therivel, Andrew Chadwick (2005) Introduction to Environmental impact assessment. Taylor and Francis

2. Richard K. Morgan (2002) Environmental impact assessment: A methodological approach. Kluwer Academics

3. David P. Lawrence (2003) Environmental impact assessment: Practical solutions torecurrent problems. John Wiley & Sons

4. Canter Larry. Environment Impact Assessment, 2nd edn., McGraw Hill Science, 1995.

5. G.J. Rau, and C.D. Wooten. Environmental Impact Analysis Handbook, McGraw Hill.Reference Book, 1980.

6. Glasson, John, Rikki Therievel and Andrew Chadwic. Introduction to Environmental Impact Assessment, 4th edn., Routledge, 2012

7. Kulkarni, Vijay and T.V. Ramchandra. Environmental Management. The Energy and Resources Institute (TERI), 2009

8. Eccleston, Charles H. Environmental Impact Assessment: A Guide to Best Professional Practices, CRC Press, 2011.

9. Morris, Peter and Riki Therivel. Methods of Environmental Impact Assessment

(Natural and Built Environment Series). Routledge, 2009.

10. P. Leelakrishnan. Environmental Law in India, 3rd edn., ButterworthsWadhwa, 2008.

11. Dwivedi, S.N., Natarajan, R and Ramachandran, S., “Coastal Zone Management in

Tamilnadu”.

Minor: Marine Biology

OS-MMB-701 Fisheries Oceanography

Module: I

Classification of fishes with special emphasis on marine fishes. Food and feeding mechanisms, reproduction, courtship and parental care. Fish eggs and larvae. Distribution and migration of fishes. Mud banks and related fishery.

Module: II

Identification and taxonomy of finfishes and shellfishes. Fishery resources of India – Fin fishes: Elasmobranchs, Oil sardines, Indian mackerel, Bombay duck, Tunas, Seer fishes, Pomfrets, Carangids, Silver bellies, Flat fishes, Ribbon fishes, Perch, Scieanids and Polynemids, Eels and Catfishes. Estuarine fishery - Milk fish, Mullet, Tilapia, Pearl spot. Marine ornamental fishes.

Shell fishes - Crustaceans – Shrimps, Crabs, Lobsters. Molluscs – Bivalves – Oysters – Pearl oyster and Edible Oyster, Mussels – *Perna viridis* and *Perna indica*, Clams. Gastropods – Chanks. Cephalopods – Squid, Cuttlefish and Octopus. Biology of Shrimps, Crabs, Molluscs and Cephalopods

Module: III

An introduction to Fishery hydrography - Influence of fishery independent factors - El Nino Southern Oscillation (ENSO) - Upwelling and fisheries - climate change and fisheries - remote sensing and fisheries - potential fishing zones

Module: IV

Common fishing crafts and gears with special reference to Indian coasts. Methods of fish detection in the sea. Fish preservation and processing in India. Storage, logistics, curing, canning, freezing and dehydration. Fishery byproducts. Export of marine products.

Module: V

An introduction to fish population dynamics and fishery conservation, overfishing and management- Surplus production model and MSYEstimation of fish catch assessment – Methods in Fishery Biology, age and growth, length-weight relationship, spawning, stage at maturity, fecundity etc. Fisheries management - Regulations - input and output controls - Seasonal fishing bans – Ecosystem-based fisheries management (EBFM), sustainability - ecolabeling - Fishery economics and trade, Blue economy.

References

1. Akhilesh, K. Singh., & Anil, Mittal. (1999). *Dictionary of Aquaculture.* Daya

Publishing House.

2. Ayyappan, S. (2011). *Handbook of Fisheries and Aquaculture*. New Delhi: ICAR.

3. Bardach, J.E.,Rythor, J.H & MeLarney, W.O. (1972). *Aquaculture: The Farming and Husbandry of Freshwater and Marine Organisms*. New York: WileyInterscience.

4. Malcolm, Beveridge. C.M. (2004). *Cage Aquaculture* (3rd Edition). Oxford: Blackwell publishing.

5. Kurian, C. V., Sebastian, V. O & Pillai, V. N (1993). *Prawns and Prawn Fisheries of India*. Hindustan Pub. Corp.

6. FAO. (2011). *Aquaculture Development: Use of Wild Fishery Resources For Capture Based Aquaculture*, FAO.

7. Jhingran, V.G. (1975). *Fish and Fisheries of India* (3rd Edition). India: Hindustan Publishing Corporation.

8. Kinne, O. (1984). *Marine Ecology* (Vol.III Parts 2 & 3). John Wiley & Sons.

9. Kumar, H D. (2003). *Sustainability and Management of Aquaculture and Fisheries*. New Delhi: Daya Publishing House.

10. Lawson, T.B. (1995). *Fundamentals of Aquaculture Engineering*. New York: Chapmanmm and Hall, 355 p.

11. Milne, P. H. (1972). *Fish and Shellfish Farming in Coastal Water*. Fishing News.

12. Walne, P. R. (1979). *Culture of Bivalve Molluscs: 50 Years of Experience at Conwy Fishing*. News Books.

13. Pillai, T.V.R. (1972). *Coastal Aquaculture in the Indo-Pacific Region*- Fishing News Books by arrangement with the Indo-Pacific Fisheries Council and the Food and Agriculture Organization of the United Nations.

14. Chondar, S.L. (1980). *Hypophysation of Indian Major Carps.* India: Satish Book Enterprise.

15. Thomas, P C. (1998). *Current and Emerging Trends in Aquaculture: Proceedings of the National Seminar*. Delhi:Daya Publishing House.

16. Wheaton, F.W. (1977). *Aquaculture Engineering* (1st Edition). Wiley Science.

17. Timmonms, M.B., Ebeling, J.M., Wheaton, F.W., Summerfelt, S.T., & Vinei, B.J. (2002). *Recirculating Aquaculture Systems* (2nd Edition). New York: Cayuga Aqua Ventures.

OS-MMB-702 Coral Reef Ecosystem

Module I

Introduction to coral reef: diversity, productivity, distribution and evolution. Distribution of coral reefs in India. Cnidarians - hydrozoans and anthozoans. Coral distribution and reef zonation. Biology of hard and soft corals. Species interaction and ecology of reefs. Photo-acclimation and photoprotection.

Module II

Coral anatomy and physiology. Coral life history, feeding habits. Reproduction and recruitment in corals. Coral reef development. Interaction between corals and their symbiotic algae, Zooxanthellae. Loss of color at depth.

Module III

Major taxa living in coral reef ecosystems: Protists, Plants, Molluscs, Annelids (polychaetes); Crustaceans (lobsters, shrimps, crabs), Echinoderms, Sponges, Bryozoans, Morays/other eels. Reef fishes and Reef fish behavior. Predators, grazers, herbivores. Cleaning symbioses.

Module IV

Coral diseases – black band disease, pinkline syndrome, white band disease and yellow band disease. Current coral reef monitoring techniques. Coral reef decline and conservation, artificial reef systems. Coral immune system

Module V

Anthropogenic impacts on tropical marine ecosystems. Threats to coral reefs. Biofouling. Pollution of the marine environment – heavy metals, petroleum hydrocarbons. Impact of Climate change on coral reef -, Sea surface warming, Ocean Acidification. Resilience of coral reefs to climate change, phase shift, palaeoclimatology.

References

1. Birkeland, C. (1997). *Life and Death of Coral Reefs*. Chapman & Hall.

2. Davidson, O. G. (1998). *The Enchanted Braid Coming to Terms with Nature on the*

Coral Reef. John Wiley & Sons, Inc.

3. Deloach, N. (1999). *Reef Fish Behaviour: Florida, Caribbean, Bahamas*. New

World Publications, Inc.

4. Humann, P., &Deloach, N. (2002). *Reef Fish Identification: Florida, Caribbean,*

Bahamas(3rdEdition). Jacksonville, FL: New World Publications.

5. Humann, P.,&Deloach, N. (2002). *Reef Coral Identification: Florida, Caribbean,*

Bahamas(2nd Edition).Jacksonville, FL: New World Publications.

6. Humann, P., N. Deloach. (2002). *Reef Creature Identification: Florida, Caribbean,*

Bahamas(2nd Edition).Jacksonville, FL: New World Publications, Inc.

7. Nybakken, J.W., &Bertness, M. D. (2004). *Marine Biology: An Ecological Approach* (6thEdition). Benjamin Cummings.

8. Smith, D.L., &Johnson, K. B. (1996). *A Guide to Marine Coastal Plankton and Marine Invertebrate Larvae*(2nd Edition). Kendall/Hunt Publishing Company.

9. Eugene, H. Kaplan. (1999).*A Field Guide to Coral Reefs of the Caribbean and Florida*. Houghton Mifflin Co.

10. Veron J.E.N (2009). A reef in Time. Harvard University Press

11. Charles R.C. Sheppard , Simone Davy, Graham M. Pilling , .Nicholas Graham (2018). The Biology of Coral Reefs. Oxford University Press

Semester: VIII

Major: DSC

OS-POC-801 Coastal Ocean Modelling

Module I

Review of coastal and estuarine process: Waves in the nearshore and surf zone, beach profiles, currents and sediment transport in the near-shore and surf zone; estuaries and tidal inlets, tidal currents, residual currents, tidal flushing.

Module II

Coastal Ocean modelling approaches – Coastal profile, coastline models and coastal area models- Input schematization - Input parameters- General principles of schematization- Tidal schematization- Schematization wind/wave climate- Coastal profile models – Principles and approach, SBEACH- Coastal area models – One line models- Principles and approach- GENESIS- Coastal area models – Flow model- Sediment Transport model- XBeach- ROMS- Delft 3D-MIKE 21.

Module III

Modelling procedure - Data collection and analysis- Conceptual model- Setting up model grid and bathymetry- Boundary conditions- Calibration and Validation- Defining output- Running and post processing- Interpretation of results- Case studies.

Module IV

Introduction on Tide Models-tidal prediction for ports and shallow water-the harmonic method- the response method- Storm surge modelling

References:

1. Paul D Komer(1998) Beach Processes and Sedimentation, Prentice Hall, 2nd Edition
2. Roelvink D and Reniers A., (2012) A Guide to Modelling Coastal Morphology, World Scientific
3. Goda, Y., (2010) Random Seas and Design of Maritime Structures, World Scientific Publishing Ltd
4. Horikawa, K.(2010) Coastal shoreline change prediction models, Won Kisool (Korea) (2010)
5. Bowden, K. F. (1984) Physical Oceanography of Coastal Waters. Ellis Hot-wood Ser. Mar. Sci., John Wiley& Sons, Inc., Somerset, N.J. 302 p.

OS-POC-802 Coastal Engineering

Module I

Coastal Engineering Problems- coastal flooding, shoreline erosion, navigation sedimentation, water quality pollution, and coastal habitat evanescence. Physical processes on coastal environment. Equation and Solution. Sediment Transport. Breakwaters tip and entrance gap- Wave-Structure Interaction- Wave Run-up- beaches- structures and slopes- Wave Overtopping- structures and slopes. Offshore piles - Design of Seawalls & Breakwaters - Design of Coastal Structures, - Basic principles of coastal processes.

Module II

Small Amplitude Wave Theory- Wave properties: Profile, celerity, velocity - Pressure, Energy and Mass Transport. Standing Waves. Wave Transmission-Wave Breaking- Height and depth-wave Forces. Define and analyze coastal problems to conceive alternative solutions

Module III

Finite-Amplitude Waves- Stokes Theory- Shallow Water Waves. Cnoidal& Solitary Wave Theory- Stream Function Theory- Long Waves: Wave Prediction, Wave Transformation, Shoaling, Refraction: Snell's law- Diffraction.

Module IV

Principles of Coastal Defence- Management and Environmental Assessment- Coastal Zone Metrics- Navigation and harbour design- Tools and procedures to plan, design, construct, and maintain coastal projects- Dredging and disposal- structure repair and rehabilitation- wetland and low-energy shore protection- risk analysis

Module V

Coastal Processes and Hazards - Coastal Geomorphology, Coastal planning and design parameters - coastal structures - coastal development/management-Numerical simulation of engineering process- Coastal Zone Modelling - hydraulic engineering works.

References:

1. Barnabe&Barnabe (2000) Ecology and management of coastal waters: The aquatic environment Springer-Praxis
2. Kamphuis, J W (2000) Introduction to Coastal Engineering and Management, World Scientific, 2000.
3. Coastal Engineering Manual Outline, USACE, 2006: http://chl.erdc.usace.army.mil/cemtoc

FINAL DISSERTAION