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ताळगांव पठार
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(Accredited by NAAC)

GU/Acad –PG/BoS -NEP/2023/79/4 Date:25.05.2023

Ref: GU/Acad –PG/BoS -NEP/2022/339/23 dated 19.08.2022

CIRCULAR

In supersession to the above referred Circular, the updated approved Syllabus with revised Course Codes of the **Master of Sciences in Marine Sciences** Programme is enclosed.

The Dean/ Vice-Deans of the School of Earth, Ocean and Atmospheric Sciences are requested to take note of the above and bring the contents of the Circular to the notice of all concerned.

ASHWIN VYAS LAWANDE
Digitally signed by ASHWIN VYAS LAWANDE
Date: 2023.05.25 17:05:07 +05'30'

(Ashwin Lawande)
Assistant Registrar – Academic-PG

To,

1. The Dean, School of Earth, Ocean and Atmospheric Sciences, Goa University.
2. The Vice-Deans, School of Earth, Ocean and Atmospheric Sciences, Goa University.

Copy to:

1. The Chairperson, Board of Studies in Marine Sciences.
2. The Programme Director, M.Sc. Marine Sciences, Goa University.
3. The Controller of Examinations, Goa University.
4. The Assistant Registrar, PG Examinations, Goa University.
5. Directorate of Internal Quality Assurance, Goa University for uploading the Syllabus on the University website.

Goa University

Syllabus of M. Sc. Marine Sciences Program

A brief description of the course

Purpose: To provide trained manpower in different branches of Marine Sciences.
Prerequisites: Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent thereto, with at least seven units of 100 marks in the first, second and third years taken together. Eligibility is B.Sc. Physics, Mathematics, Electronics, Computer Science, IT, Chemistry, Industrial Chemistry, Analytical Chemistry, Pharmaceutical Chemistry, Botany, Zoology, Microbiology, Biotechnology, Biosciences, Fisheries, Aquatic Sciences, Earth Sciences, Geology and equivalence.

Credits (theory and practical): 1 credit (theory) shall be equivalent to 15 clock hours of contact teaching. 15 clock hours are inclusive of lectures/group discussion/seminars/problem-solving/tutorials/assessments, etc. 1 credit (practical) shall be equivalent to 30 clock hours of contact teaching, i.e. 15 practicals of 2 clock hours duration each. The assessment of the courses shall be fully internal. The evaluation of the courses shall be by continuous assessment. The weightage of marks for intra and semester-end examinations in both theory and practical courses shall be 60:40. The assessment and evaluation of all the courses will be carried out as per OA 35. The duration of all comprehensive written Semester End Assessment (SEA) examinations carrying 25 marks or less, shall be of one hour; SEA carrying above 25 marks up to 50 marks shall be two hours.

Number of semesters and how the courses are distributed: The students will be eligible for the Master's degree on the successful completion of courses equivalent to 80 credits. A student shall not be allowed to register for less than 10 credits and more than 25 credits in a semester. A student must obtain 32 core, 08 discipline-specific and 08 research-specific credits from the parent discipline. The remaining 16 generic/research credits may be earned by the student by opting for courses (electives) either from the parent discipline or any other discipline of the University.

Dissertation: A dissertation is compulsory and will have 16 credits. Topics will be assigned at the end of 2nd semester and the study will begin from starting of 3rd semester. There will be continuous internal monitoring by the guiding/supervising teacher.

Field Studies: M. Sc. Marine Sciences involves regular onboard training on research vessel/boat.

Semester I		
Discipline Specific Core Courses		
Course Code	Course Title	Credit(s)
MSC 500	Physical Oceanography	3
MSC 501	Physical Oceanography Practical	1
MSC 502	Marine Chemistry	3
MSC 503	Marine Chemistry Practical	1
MSC 504	Marine Biology	3
MSC 505	Marine Biology Practical	1
MSC 506	Marine Geology	3
MSC 507	Marine Geology Practical	1
Discipline Specific Elective Courses		
MSC 521	Ocean-Atmosphere Coupling and Climate	3
MSC 522	Ocean-Atmosphere Coupling and Climate Practical	1
MSC 523	Marine Geochemistry	3
MSC 524	Marine Geochemistry Practical	1
MSC 525	Marine Ecology	3
MSC 526	Marine Ecology Practical	1
MSC 527	Principles of Mineralogy and Geochemistry	3
MSC 528	Principles of Mineralogy and Geochemistry Practical	1

Total Number of Credits: 20; Core: 16, Elective: 04; Theory: 15, Practical: 05

Semester II		
Discipline Specific Core Courses		
Course Code	Course Title	Credit(s)
MSC 508	Estuarine and Coastal Physical Oceanography	3
MSC 509	Estuarine and Coastal Physical Oceanography Practical	1
MSC 510	Estuarine and Coastal Chemistry	3
MSC 511	Estuarine and Coastal Chemistry Practical	1
MSC 512	Estuarine and Coastal Biology	3
MSC 513	Estuarine and Coastal Biology Practical	1
MSC 514	Estuarine and Coastal Geology	3
MSC 515	Estuarine and Coastal Geology Practical	1
Discipline Specifeic Elective Courses		
MSC 529	Geophysical Fluid Dynamics	3
MSC 530	Geophysical Fluid Dynamics Practical	1
MSC 531	Marine Pollution	3
MSC 532	Marine Pollution Practical	1

MSC 533	Marine Microbial Ecology	3
MSC 534	Marine Microbial Ecology Practical	1
MSC 535	Sedimentology	3
MSC 536	Sedimentology Practical	1

Total Number of Credits: 20; Core: 16, Elective: 04; Theory: 15, Practical: 05

Semester III		
Research-Specific Elective Courses		
Course Code	Course Title	Credit(s)
MSC 600	Computational Methods – I	2
MSC 601	Computational Methods Practical – I	2
MSC 602	Computational Methods – II	2
MSC 603	Field Sampling	1
MSC 604	Field Sampling Practical	1
MSC 605	Research Methodology – Physical Oceanography	1
MSC 606	Research Methodology – Chemical Oceanography	1
MSC 607	Research Methodology – Biological Oceanography	1
MSC 608	Research Methodology – Geological Oceanography	1
Total = 08 credits		

Generic Specific Elective Courses		
Course Code	Course Title	Credit(s)
MSC 621	Remote Sensing and its Applications	3
MSC 622	Remote Sensing and its Applications Practical	1
MSC 623	Dynamic Oceanography	3
MSC 624	Dynamic Oceanography Practical	1
MSC 625	Analytical Chemistry of Seawater and Natural Products	3
MSC 626	Analytical Chemistry of Seawater Practical	1
MSC 627	Metal Bioavailability, Bioaccumulation and Phyto-remediation	3
MSC 628	Metal Bioavailability, Bioaccumulation and Phyto-remediation Practical	1
MSC 629	Marine Biodiversity	3
MSC 630	Marine Biodiversity Practical	1
MSC 631	Aquaculture	3
MSC 632	Aquaculture Practical	1
MSC 633	Tectonics, Geophysics and Structural Geology	3
MSC 634	Tectonics, Geophysics and Structural Geology Practical	1
Total = 12 credits		

Semester IV		
Research-Specific Elective Courses		
Course Code	Course Title	Credit(s)
MSC 609	Academic Research Practices	1
MSC 610	Advanced Research Analyses	1
MSC 611	Fundamentals of Intellectual Property Rights and Patents	1
MSC 612	Scientific Writing	1
MSC 613	Capture Fisheries and Overfishing	1
MSC 614	Tropical Cyclones	1
MSC 615	Nitrogen and Climate Change	1

MSC 616	Air Pollution	1
Total = 04 credits		

Discipline Specific Dissertation / Internship		
Course Code	Course Title	Credit(s)
MSC 617	Discipline Specific Dissertation	16
Total = 16 credits		

SEMESTER I

Name of the Programme: M.Sc.Marine Sciences
Course Code: MSC 500
Title of the Course: Physical Oceanography
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	A degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Course Objective:	To provide a basic understanding of physical oceanographic variables and processes	
Content:	**Module I** Oceanographic explorations – Evolution of theoretical ideas – Units used in oceanography – The role of observations in oceanography – Ocean and seas – Dimensions of the ocean – Physical properties of water – Influence of dissolved salts – Physical properties of sea-water – Salinity – Temperature – Density – Distribution of temperature, salinity and density in low, mid and high latitudes and their seasonal variations – Oceanic mixed layer and thermo-cline – Instruments used for the measurement of temperature and salinity – Sound in the sea – Propagation of sound in the sea – Light in the sea – The oceanic heat budget – Shortwave radiation, longwave radiation – Sensible and latent heat fluxes and net heat flux – Bowen's ratio – T.S.V. diagram – T.S. diagram. **Module II** The earth in space – Composition of atmosphere – Vertical extent of atmosphere – Measurement of wind – Calculations of wind stress – Coriolis force – General circulation of atmosphere – Atmospheric temperature – Temperature systems and scales – Atmospheric humidity – Vapour pressure – Ocean Circulation: Wind-driven and thermo-haline circulations – Sea ice. **Module III** Equatorial processes – El niño and Southern Oscillation and their tele-connections – Indian Ocean Dipole (IOD) – Indian Ocean Circulation – Oceanic fronts – Upwelling: open ocean and coastal upwelling – Water masses in the ocean: Bottom water, Deep water, Antarctic intermediate water, Central water, Arabian Sea, Persian Gulf, Red Sea water masses and Bay of Bengal water – Lagrangian and Eulerian methods for measuring currents.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments	

References/ Readings:	1.Colling A. (2001), *Ocean circulation (Second Edition) (Vol. 3)*. Butterworth-Heinemann in association with The Open University. 2.Wright J. & Colling A. (1995) *Seawater: its composition, properties, and behavior (Second Edition)*. Pergamon Press, in association with the Open University. 3.Talley L. D., Pickard G. B., Emery W. J. & Swift J. H. (2011). *Descriptive physical oceanography: an introduction (Sixth Edition)*. Academic press. 4.Neumann, G. S., & Pierson Jr., W. J. (1966). Principles of physical oceanography. Englewood Cliffs, New Jersey, U.S.A.: Prentice-Hall 5.Ahrens, C. D. (1985). *Meteorology today: an introduction to weather, climate, and the environment (Second Edition)*. St. Paul, Minnesota, U.S.A.: West Publishing. 6.Wells, N. C. (2012). *The atmosphere and ocean: a physical introduction*. Chichester, West-Sussex, U.K.: Wiley-Blackwell. 7.Pal, A. S. (2001). *Introduction to micrometeorology (Second Edition)*. Academic Press. 8.Tomczak, M., & Godfrey, J. S. (2001). Regional Oceanography: an Introduction. Online edition. https://www.geo.uni-bremen.de/~apau/dynamicclimate/course_materials_2015/Resources/tomczak_godfrey_1994.pdf 9.Stewart, R. H. (2008). *Introduction to physical oceanography*. Robert H. Stewart. https://open.umn.edu/opentextbooks/textbooks/20	
Course Outcomes:	1. An understanding of basic physical oceanographic processes in different parts of the world ocean. 2. Ocean circulation. 3. Information on international explorations.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 501
Title of the Course: Physical Oceanography Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To develop an ability to analyse physical oceanographic properties and decipher associated processes	
Content:	Analysis of vertical profiles of temperature, salinity and density to understand the physical processes at low, mid and high latitudes of the world ocean (6 hours; References 1 and 2) Distinguish variation in properties of upwelling and non-upwelling periods/ regions using a) temperature, b) salinity and c) density (3 hours; References 1 and 2) Vertical section of temperature to study the physical processes along a transect (6 hours; References 1, 2 and 3) Vertical section of salinity to study the physical processes along a transect (6 hours; References 1, 2 and 3) Vertical section of density to study the physical processes along a transect (6 hours; References 1, 2 and 3) Estimation and analysis of heat content in different parts of World Ocean (3 hours; References 4 and 5)	30 hrs.
Pedagogy:	Tutorials/ assignments/ practical/ field study	

References/Readings:	1.Wright, J., & Colling, A. (1995). *Seawater: its composition, properties, and behavior (Second Edition)*. Pergamon Press, in association with the Open University. 2.Stewart, R. H. (2008). *Introduction to physical oceanography*. Robert H. Stewart. https://open.umn.edu/opentextbooks/textbooks/20 3.Colling, A. (2001). *Ocean circulation* (Second Edition) (Vol. 3). Butterworth-Heinemann in association with The Open University. 4.Tomczak, M., & Godfrey, J. S. (2001). Regional Oceanography: an Introduction. Online edition. https://www.geo.uni-bremen.de/~apau/dynamicclimate/course_materials_2015/Resources/tomczak_godfrey_1994.pdf 5.Fofonoff, N. P., & Millard Jr., R. C. (1983). Algorithms for the computation of fundamental properties of seawater. UNESCO Technical Papers in Marine Science 44, Endorsed by UNESCO/SCOR/ICES/IAPSO/ Joint Panel on Oceanographic Tables and Standards and SCOR Working Group 51; Place de Fontenoy, Paris, France: UNESCO. d.o.i.: https://doi.org/10.25607/OBP-1450	
Course Outcome:	1. An ability to explain processes based on variations of the conservative properties of ocean and describe spatial and temporal variation of ocean processes.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 502
Title of the Course: Marine Chemistry
Number of Credits: 03
Effective from AY:2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To learn the basic concepts of the chemistry of the marine environment that concerns the study of the properties and interactions of the substances.	
Content:	**Module I** Symbols and units used in chemical oceanography – Major and minor elements in seawater – Geochemical balance of the oceans – Goldschmidt material balance – cycle of cationic and anionic species in the lithosphere, atmosphere, hydrosphere and biosphere systems, residence time of the elements in the ocean, chemical speciation in seawater – Dissolved species – Particulate species – Activity coefficient – Hydration of ion in seawater. **Module II** Constancy of relative ionic composition of seawater, conditions under which major elements may not be conservative, factors affecting the distribution of trace elements in the sea, interaction of trace elements with marine organisms, enrichment factor, vertical distribution of trace elements in the ocean, Chlorinity and salinity: definition and significance, practical salinity scale, Radioactive nuclides in the sea, Redox chemistry of seawater. **Module III** Dissolved gases (other than CO_2) in seawater – Basic concepts : effect of pressure, salinity, temperature on solubility of gases in seawater, air – sea gas exchange, processes affecting their distribution, dissolved oxygen in the ocean – Dissolved gases (CO_2) in seawater – Carbon dioxide equilibria in seawater; pH, Total, carbonate and Borate alkalinity, and buffering capacity of oceans: components of CO_2 system in seawater – Percentage composition of inorganic carbon; calcium carbonate precipitation and dissolution phenomena – Lyso-cline and carbonate compensation depth.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments/ self-study	
References/ Readings:	1.Riley, J. P., Chester, R. (1971). Introduction to Marine Chemistry. Academic Press. 2.Riley, J. P., Skirrow, G. (1975). Chemical Oceanography. Academic Press. 3.Horne, R. A. (1969). Marine Chemistry. Wiley-Interscience. 4.Wright, J., Wright, J.,Colling, A. (2004). Seawater: Its composition, properties & behaviour. Oxford: Butterworth-Heinemann in association with the Open University.	

	5.Martin, D. F. (1970). Marine Chemistry. NY: Marcel Dekker. 6.Millero, F. J., Sohn, M. L. (1992). Chemical Oceanography. CRC Press. 7.Burton, J. D., Brewer, P. G., Chesselet, R. (1986). Dynamic Processes in the Chemistry of the Upper Ocean. Plenum Press. 8.Holland, H. D. (1978). The chemistry of the Atmosphere and Oceans. Wiley. 9.Bengtsson, L. O., Hammer, C. U. (2001). Geosphere – Biosphere Interactions and Climate. Cambridge University Press. 10.Sengupta, R., Naqvi, S. W. A. (1984). Chemical Oceanography of the Indian Ocean, North of Equator. Deep Sea Research, 31A, 671-706. 11.Millero, F. J. (2005). Chemical Oceanography. CRC Press. 12.Liss, P. S., Duce, R. A. (1997). The Sea Surface and Global Change. Cambridge University Press. 13.Fasham, M., Fasham, M. J. R. (2003). Ocean Biogeochemistry: The role of the ocean carbon cycle in Global change. Springer. 14.Turekian, K. K. (2010). Marine Chemistry and Geochemistry. Academic Press.	
Course Outcomes:	1. A comprehensive understanding of the properties and interactions of the chemical substances present in the marine environment. 2. To understand the key chemical processes regulating the marine environment. 3. To understand the distribution of dissolved O_2 and the biogeochemical cycling of the metals in the marine environment.	

Name of the Programme:M. Sc.Marine Sciences
Course Code: MSC 503
Title of the Course: Marine Chemistry Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	This course deals with the analytical chemistry of the Seawater.	
Content:	Estimation of salinity of seawater by the Mohr- Knudsen chlorinity titration method (5 hours; Reference 1) Estimation of salinity of seawater by Harvey's method (5 hours; References 1, 3, 4) Determination of dissolved O_2 of seawater by Winkler's iodometric titration method (5 hours; Reference 1) Determination of pH of seawater by potentiometric method using pH meter and determination of total alkalinity of seawater by potentiometric titration using pH meter (5 hours; Reference 1) Estimation of carbonate and bicarbonate alkalinity by titrimetric method (5 hours; Reference 4) Spectrophotometry: Verification of Beer's law (5 hours; Reference 2)	30 hrs.
Pedagogy:	Laboratory experiments/ field studies	
References/ Readings:	1.Grasshoff, K., Ehrhardt, M., Kremling, K. (1983). Methods of Seawater Analysis. VerlagChemie, Weinheim. 2.Ewing, G. W. (1981). Instrumental Methods of Chemical Analysis. NY: McGraw-Hill. 3.Parsons, T. R., Maita, Y.,Lalli, C. M. (1984). A Manual of Chemical and 4.Biological Methods for Seawater Analysis. Oxford: Pergamon Press. Martin, D. F. (1972). Marine Chemistry. NY: Marcel Dekker.	
Course Outcomes:	1. To develop analytical skills to determine the concentrations of various chemical parameters.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 504
Title of the Course: Marine Biology
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	Introduction of marine life, biological processes to elucidate the ecosystem function. Further, it also provides an insight on larval ecology, trophic levels and their role in supporting life in marine environment.	
Content:	M**odule I** Introduction to marine biology – oceanographic processes, history, classification, theories, expeditions, hypothesis testing; Origin of life – life processes, abio-genesis, theories of natural selection, organic evolution, primordial soup hypothesis, organic molecules, chemical evolution, iron sulfide and black smoker's theory, RNA world hypothesis, theory of evolution and panspermia, Theory of evolution. **Module II** Basic ecological concepts and marine biotic structure, marine larval ecology, larval types and strategies, and bi-phased life cycle, Marine and coastal environment, biological zonation, inter-tidal ecosystem - rocky shore - zonation pattern - physical and biological factors, sandy shores and protected sand flats - physical and biological factors, faunal composition and adaptations. **Module III** Sea as biological environment - physiological changes, regulators and conformers, scope for growth, temperature and metabolic rates, Production and distribution organic matter, microbial loop, re-mineralization. Primary productivity - mechanism, light and dark reaction, intermediate products, factor affecting primary productivity, role of pigments, methods of assessment, biological pump and transformation of organic matter, vertical profile of primary productivity and SCM, turbulence and MLD, Human impact and biological productivity.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	lectures/ tutorials/ assignments/ self-study	
References/Readings:	1.Peter Castro and Michael Huber, 2018, Marine Biology, 11th Edition, McGraw-Hill Publication, Ogden, USA. 2.Karleskint, George, Turner, Richard, Small, James, 2012, Introduction to Marine Biology , 4th Edition Cengage Learning, South-Western Macmillan, USA. 3.Carol Lalli, C.M. and Thimothy Parson, 1997, Biological Oceanography – An Introduction, (2nd edition) –, Elsevier Ltd.	

	Amsterdam, Netherlands. Nair, N.B. & Thampy, D.M , 1980, Textbook of Marine Ecology, ., Macmillan, London. 4.Herbert H. Thurman, Harold.V. Webber, 1991, Marine Biology, Harper Collins Publishers, New York City. 5.Lewis, J.R, 1965, The Ecology of Rocky Coasts, English Universities Press, London. 6.J. H. Price; D. E. G. Irvine; W. F. Farnham, 1980, The Shore Environment. Volume 1 & 2: Methods and Ecosystems , W.F. Systematics Association, Cambridge University Press, UK. 7.R. S. K. Barnes, Peter P. Calow, P. J. W. Olive, D. W. Golding, J. I. Spice . 1986, The Invertebrates (3rd Edn.),–, Wiley-Blackwell Science, New Jersey, USA. 8.James W. Nybakken and Mark D. Bertness, 2005, Marine Biology: An Ecological Approach, 6th Edition,–, Pearson/Benjamin Cummings, San Francisco.	
Course Outcomes:	1.Provides fundamental knowledge related to marine life and processes. 2.To elucidate various strategies adopted by marine organisms for survival. 3.To understand process and factors responsible for primary productivity.	

Name of the Programme:M. Sc.Marine Sciences
Course Code: MSC 505
Title of the Course: Marine Biology Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To gain information on sampling devices used for collection of marine organisms and identification of some of the major groups.	
Content:	Introduction to standard sampling devices / instruments employed for collection and analysis of biological parameters in water and sediments used in oceanographic studies (4 hours; References 1, 2) Design and execution of field / sampling surveys for collection of water and sediment samples (2 hours; Reference 2) Analysis of biological communities (water and sediment), their preservation and storage techniques using standard methods (4 hours; Reference 2) Quantitative estimation & identification of phytoplankton in seawater (6 hours; References 3, 4) Quantitative estimation of zooplankton using volume displacement, wet weight and dry weight method (3 hours; Reference 5) Qualitative estimation of zooplankton using stereoscopic microscope (6 hours; Reference 5) Quantitative and qualitative estimation of benthic invertebrates (5 hours; References 6, 7, 8, 9)	30 hrs.
Pedagogy:	Demonstrations/ practical/ designing of experiments/ identification techniques	
References/ Readings:	1.Steele, J. H., Thorpe, S. A., & Turekian, K.K. (2010). *Marine Ecological Processes: A derivative of Encyclopaedia of Ocean Sciences* (2nd ed). Academic Press, San Diego, CA (USA). 2.Intergovernmental Oceanographic Commission (1994) *Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements*. Paris, France, UNESCO-IOC, 170pp. (Intergovernmental Oceanographic Commission Manuals and Guides: 29), (JGOFS Report; 19). DOI: https://doi.org/10.25607/OBP-1409. 3.Verlecar, X. N., Desai, S. R. (2004). Phytoplankton Identification Manual.National Institute of Oceanography, Dona Paula, Goa. 4.Goswami, S. C. 2004 Zooplankton methodology, collection and identification- a field manual. National Institute of Oceanography, Dona Paula, Goa. 5.Tagliapietra, D., Sigovini, M. (2010). Benthic fauna: collection and identification of macro-benthic invertebrates. In J. Dominik et al. (Eds.) *Terre et Environment*, *88* (pp. 253–261), Section des Science de la Terre, Université de Genève. 6.Barnes, R. D. (1980). *Invertebrates Zoology* (4th ed), Philadelphia: Saunders College. 7.Day, J. H. (1967). *A monograph on the Polychaeta of Southern*	

	Africa. Natural History Museum (London) Publications. 8.Lyla, P.S., Velvizhi, S., Ajmal Khan, S. (1999). *A monograph on the amphipods of Parangipettai coast.*Annamalai University, India.	
Course Outcome:	1. Develop ability to identify marine biota at species level.	

Name of the Programme:M. Sc.Marine Sciences
Course Code: MSC 506
Title of the Course: Marine Geology
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To introduces basic concepts of Marine Geology to understand ocean basins, their dimensions, tectonics and evolution. Sediment components and processes with special reference to near-shore and beach dynamics; ocean mineral resources – application of fossils in paleoclimate and monsoon.	
Content:	**Module I** The earth and the solar system-origin and age of the earth - internal structure - Geological time scale – Size and shape of the ocean basins: Pacific, Atlantic and Indian – Morphology and structure of continental margins, mid oceanic ridges and deep sea floor – Origin of ocean basins – Continental drift, sea floor spreading and plate tectonics – Evolution of the Indian ocean. **Module II** Sediment, sediment grade scale and analysis – Classification, composition, distribution and source of sediments with emphasis on near shore areas – Surveying, sampling and laboratory techniques for the study of coastal and estuarine sediments – Analysis of sedimentological data and interpretation – Instruments used in marine geology. Beach and beach profile, variations in beach morphology and its significance – Near shore geological processes: erosion, transportation and deposition. **Module III** Sea bed minerals with emphasis on Indian ocean – Polymetallic nodules, phosphorites, carbonates, placer deposits and petroleum resources, gas hydrates – Fossilization process – Types of microfossils and classification, technique for paleoclimate reconstruction with respect to oxygen isotope studies, role of microfossils in paleo – oceanography, paleoclimate, marine archaeology, petroleum exploration and monitoring marine pollution & mitigation.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings:	1.Boersma, A., & Haq, B. U. (Eds.). (1978). Introduction to marine micropaleontology. Elsevier. 2.Cam, K. (1972). Beaches and coasts.Edward Arnold, London. 3.Dyer, K. R. (1986). Coastal and estuarine sediment dynamics. Chichester: Wiley. 4.Gross, M. G. (1972). Oceanography: a view of the earth. Englewood Cliffs, N.J: Prentice-Hall. 5.Haq, B. U., & Milliman, J. D. (1985). Marine geology and oceanography of	

	Arabian Sea and coastal Pakistan. 6.Haq, Bilal U. & Milliman, John D. (1984). Marine geology and oceanography of Arabian Sea and coastal Pakistan. New York : Van Nostrand Reinhold/Scientific and Academic Editions 7.Kennett, J. P. (1982). Marine geology. Prentice Hall INC Englewood, Cliffs, N. J. 07632 8.Komar, P. D. (1976). Beach processes and sedimentation. Englewood Cliffs, N.J: Prentice-Hall. 9.Petrushevskaya, M. G., Funnel, B. M., & Riedel, W. R. (1971). Micropaleontology of the Oceans. 10.Skinner, B. J. (1969). Earth resources. Englewood Cliffs, N.J.: Prentice-Hall. 11.Teleki, P. G., Dobson, M. R., Moore, J. R., & von Stackelberg, U. (Eds.). (2012). Marine minerals: advances in research and resource assessment (Vol. 194). Springer Science & Business Media. 12.Thurman, H. V., & Trujillo, A. P. (2004). Introductory oceanography. Upper Saddle River, N.J: Pearson Prentice Hall.
Course Outcomes:	1. Understanding earth processes, evolution and mineral resources associated with ocean basins. 2. Ability to reconstruct paleoclimate and paleo-monsoon. 3. Mineral exploration in the marine environment.

Name of the Programme:M. Sc.Marine Sciences
Course Code: MSC 507
Title of the Course: Marine Geology Practical
Number of Credits: 01
Effective from AY:2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To introduce techniques to measure parameters to understand near-shore and beach dynamics, bathymetry and heavy minerals.	
Content:	Field survey (Beach) - locating a station using compass and GPS; Beach profile measurement and sediment sample collection from different parts of the beach (4 hours; Reference 2) Plotting station locations on the base map and beach profile; volume computation from the given data (2 hours; Reference 2) Conning and quartering, pre-treatment of sediment sample to remove calcium carbonate, organic matter and ferruginous material (2 hours; References 1, 6) Grain size analysis (sand) using Ro-tap sieve shaker – batch I (8 hours; References 1, 6) Computation of weight and cumulative percentages, plotting frequency and probability graphs, computation of modes of transport and grain size parameters and interpretation (4 hours; References 1, 6) Heavy mineral separation from different fractions of sand and interpretation (4 hours; Reference 1) Plot bathymetry lines and interpret geomorphology (4 hours; Reference 4) Identification of microfossils under binocular microscope & its applications in paleoclimate. (2 hours; Reference 6)	30 hrs.
Pedagogy:	Field surveys and sampling / Laboratory experiments / Computations / Plotting and interpretations	
References/ Readings:	1.Friedman, G. M., & Johnson, K. G. (1982). Exercises in sedimentology. New York: Wiley. 2.Dionne, J.C. (1978). Komar, P.D. (1976). Beach Processes and Sedimentation, Englewood Cliffs (New Jersey), Prentice-Hall. 3.Krone, R. B., (1962). Flume studies of the transport of sediment in estuarial shoaling processes: Final report. Berkeley: Hydraulic Engineering Laboratory and Sanitary Engineering Research Laboratory, University of California. 4.Babu, S. K. & Sinha, D. K. (1987): Sedimentary Petrology Practical, CBS Pub., N. Delhi. 5.Mero, J. L. (1965). The mineral resources of the sea. Amsterdam: Elsevier Pub. Co. 6.Saraswati, P. K., & Srinivasan, M. S. (2015). Micropaleontology: Principles and applications. 7.Jones, E J. W. Marine Geophysics. Chichester: Wiley, 1999. Print.	
Course Outcome:	1.Conducting field surveys, sampling and laboratory experiments to understand geological processes.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 521
Title of the Course: Ocean-Atmosphere Coupling and Climate
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To learn exchange of mass and energy across air-sea interface and its role in global climate.	
Content:	**Module I** Wind generation, forces acting on wind, wind stress, Methods of estimation of wind stress, drag coefficient – Geostrophic winds, cyclostrophic winds, thermal winds – Wind wave generation – Scales of interactions, General character of sea surface as a lower boundary of air flow – Geometry of the sea surface: Gravity waves, Wavelets and ripples, Sea-surface slopes, Slicks on the sea surface – Wind streaks, Periodic bands, Intermittent rippling, Non-periodic slicks – Instruments used in marine meteorology **Module II** The wind field in the maritime frictional layer in thermal indifferent conditions: Observational challenges, Theoretical considerations, Simplifying conditions, Hydrodynamic analogy – Austausch coefficient – Dynamic roughness – Measured wind profiles – General consideration of air-sea interaction – Planetary boundary layer – Laminar boundary layer, surface layer and Ekman layer **Module III** Determination of air-sea fluxes – Profile method and non-profile methods – Variation of air-sea fluxes with special reference to upwelling – Indian Summer Monsoons: causes, inter-annual and intra-seasonal variability, Monsoon trough, Low-Level Jet (LLJ), Tibetan Low, Mascarenhas High, tropical easterly jet (T.E.J.), Madden-Julian Oscillation (M.J.O.), Relationship of El niño, La niña and Indian Ocean Dipole (I.O.D.) in Indian Monsoon. Concepts in climatology – Radiation and its role on tropical circulation – Role of ocean heat fluxes in influencing climate change.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments	

References/ Readings:	1.Nakamura, H., Isobe, A., Minobe, S., Mitsudera, H., Nonaka, M., & Suga, T. (2016). *Hot Spots in the Climate System: New Developments in the Extratropical Ocean-Atmosphere Interaction Research.* Springer Japan. d.o.i.: https://doi.org/10.1007/978-4-431-56053-1 2.Bortkovskii, R. S. (1987). *Air-Sea Exchange of Heat and Moisture During Storms.* Revised English edition by Edward C. Monahan. Springer Netherlands. 3.Roll, H. U. (1965). Physics of the marine atmosphere. *International Geophysics Series*, Vol. *7*. [Ed.] J. van Miegham. London: Academic Press. 4.Asnani, G. C. (1993). *Tropical meteorology (Volume 1).* Pune, India: Asnani, Indian Inst. of Tropical Meteorology. 5.Asnani, G. C. (1993). *Tropical meteorology (Volume 2).* Pune, India: Asnani, Indian Inst. of Tropical Meteorology. 6.Keshavamurthy, R. N., & Rao, M. S. (1992). *The physics of monsoons*. New Delhi, Bombay, Calcutta, Madras, Nagpur, Ahmedabad, Bangalore, Hyderabad, Lucknow: Allied Publishers Limited. 7.Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., Rama, B. (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press. In Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/ 8.Wallace, J. M., & Hobbs, P. V. (2006). *Atmospheric science: an introductory survey (Second Edition)*. Academic Press. 9.Wells, N. C. (2012). *The atmosphere and ocean: a physical introduction*. Chichester, West-Sussex, U.K.: Wiley-Blackwell.	
Course Outcomes:	1.An insight about the exchange of momentum and ocean heat flux and their role in climate. 2.An understanding of the south-west monsoon and the formation and decay of tropical cyclones. 3.To understand the process of generation of winds, formation of waves and also growth and decay of El niño and La niña.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 522
Title of the Course: Ocean-Atmosphere Coupling and Climate Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To analyse air-sea fluxes associated with different oceanic-atmospheric processes in the different parts of the world ocean.	
Content:	Data extraction from global data sets of shortwave radiation and analysis of its distribution/variation (6 hours; References 1, 2, 3, 4) Data extraction from global data sets of long wave radiation and analysis of its distribution (6 hours; References 1, 2, 3, 4) Data extraction from global data sets of sensible heat flux and analysis of its distribution (6 hours; References 1, 2, 3, 4) Data extraction from global data sets of latent heat flux and analysis of its distribution (6 hours; References 1, 2, 3, 4) Estimation of net heat flux from above extracted data sets and analysis of its distribution (6 hours; References 1, 2, 3, 4)	30 hrs.
Pedagogy:	Tutorials/ assignments/ practical	
References/ Readings:	1.Roll, H. U. (1965). Physics of the marine atmosphere. *International Geophysics Series*, Vol. *7*. [Ed.] J. van Miegham. London: Academic Press. 2.Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A., Rama, B. (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press. In Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/ 3.da Silva, A. M., Young, C. C., & Levitus, S. (1994). *Atlas of surface marine data 1994, Vol. 1: Algorithms and procedures. NOAA Atlas NESDIS, 6.* Washington, D.C., U.S.A.: Department of Commerce. 4.Berry, D. I., & Kent, E. C. (2011). Air–sea fluxes from ICOADS: The construction of a new gridded dataset with uncertainty estimates. *International Journal of Climatology*, *31*(7), 987–1001. d.o.i.: 10.1002/joc.2059. https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.2059 5.Asnani, G. C. (1993). *Tropical meteorology (Volume 1).* Pune, India: Asnani, Indian Inst. of Tropical Meteorology. 6.Asnani, G. C. (1993). *Tropical meteorology (Volume 2).* Pune, India: Asnani, Indian Inst. of Tropical Meteorology. 7.Wells, N. C. (2012). *The atmosphere and ocean: a physical introduction*. Chichester, West-Sussex, U.K.: Wiley-Blackwell.	

	Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J. B. R., Maycock, T.K., Waterfield, T., Yelekçi, O., Yu, R., & Zhou, B. (2021). *IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/ 8.Shukla, P. R., Skea, J., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., & Malley, J. (2022). *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, NY, USA: Cambridge University Press. doi: 10.1017/9781009157926 . https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/ 9.Houghton, J. T., Meira Filho, L. G., Callander, B. A., Harris, N., Kattenberg, A., & Maskell, K. (1996). *Climate change 1995: The science of climate change: contribution of working group I to the second assessment report of the Intergovernmental Panel on Climate Change* (Vol. 2). Cambridge University Press. https://digitallibrary.un.org/record/223181?ln=en	
Course Outcome:	1. An ability to explain spatio-temporal variability of fluxes and identify the possible governing factors.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 523
Title of the Course: Marine Geochemistry
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To introduce concepts of Marine Geochemistry to understand processes associated with energy and material transfer from land to sea.	
Content:	**Module I** Geochemical classification of elements - distribution and abundance of elements in lithosphere – Principle geochemical cycle, Chemical weathering. Suspended matter – Methods of collection and analysis, variation, composition of total suspended particulate matter in the ocean - settling rates of suspended matter - Physico-chemical factors in sedimentation - ionic potential, hydrogen ion concentration, redox potential and colloids – Behavior of major and trace elements during sedimentation - Geochemistry of deep-sea sediments – Application of major and minor elements in the reconstruction of marine paleo-environment. **Module II** Chemical and biological aspects of dissolved organic matter in the sea – Sources of supply and processes of removal of dissolved organic matter. Radioactivity – Classification – Primary, cosmogenic and artificial radio nuclides; distribution and occurrence of radionuclides, their properties in the marine environment and their decay series – Sampling and storage of radionuclides, radio chemical separation- Applications of radionuclides to the geochronology of marine sediments and rocks – Carbon dating methods in marine sediments, oceanic mixing and residence time. **Module III** The solid-solution interface – Electro-kinetic phenomena, The electrical double layer, the structure of water at the solid solution interface, surface chemistry of oxides, hydroxides and oxide minerals; the colloidal state, origin of surface charge, aggregation of colloids, the role of coagulation in natural waters – Surface phenomena – Langmuir and Freundlich Adsorption isotherms, trace metal partitioning on solid-solution phases, particle concentration effects.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures / Assignments / Seminars / Discussion	

References/ Readings:	1.Krauskopf, K. B. (1967). Introduction to Geochemistry. Mc.Graw-hill. 2.Goldschmidt, V. (1962). Geochemistry. Clarendon press.. 3.Mason, B., Moore, B. (1956). Principles of Geochemistry. John Wiley & Sons, Inc. 4.Riley, J. P., Skirrow, G. (1975). Chemical Oceanography. N.Y.: Academic Press. 5.Krauskopf, K. B., Bird, D. K. (1995). Introduction to Geochemistry. Mc-Graw Hill. 6.Drever, J. I. (1982). The Geochemistry of Natural Waters. Englewood Cliffs, NJ: Prentice-Hall, Inc. 7.Burton, J. D., Liss, P. S. (1976). Estuarine Chemistry. Academic Press. 8.Stumm, W., Morgan, J. J. (1996). Aquatic Chemistry. NY: Wiley Interscience. 9.Stumm, W. (1987). Aquatic Surface Chemistry. NY: Wiley Interscience. 10.Home, R. A. (1969). Marine Chemistry. NY: Reinhold Publishing Corporation.	
Course Outcomes:	1.To understand geochemical processes involved in the transfer of material from land to sea. 2. To understand resources and supply of DOM and POM into the sea. 3. To understand the electrical double layer.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 524
Title of the Course: Marine Geochemistry Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objectives:	To determine quantitatively the composition of Earth and to discover laws which control the distribution of individual elements. The chemical analysis of sediment to analyze the concentration of different constituents.	
Content:	Determination of organic carbon in sediment by titrimetric method. (6 hours; References 1, 3) Determination of phosphorus in sediment. (6 hours; References 1, 2, 3) Digestion of sediment using HF:HNO_3:$HClO_4$ acid mixture. (8 hours; References 3, 6) Estimation of Cr in sediment (5 hours; References 3, 4, 5, 6) Estimation of Zn in sediment (5 hours; References 3, 4, 5, 6)	30 hrs.
Pedagogy:	Demonstrations/ Laboratory experiments	
References/ Readings	1.Grasshoff, K., Ehrhardt, M., Kremling, K. (1983). Methods of Seawater Analysis. VerlagChemie, Weinheim. 2.Parsons, T. R., Maita, Y., Lalli, C. M. (1984). A Manual of Chemical and Biological Methods for Seawater Analysis. Oxford: Pergamon Press. 3.Loring, D. H., Rantala, R. T. (1992). Manual for Geochemical Analysis of Marine Sediments and Suspended Particulate Matter. Earth Science Reviews, 32, 235-283. 4.Riley, J. P., Skirrow, G. (1975). Chemical Oceanography. Academic Press. 5.Rice, E. W., Bridgewater, L. (2012). Standard Methods for the Examination of Water and Waste Water Analysis. Washington DC: American Public Health Association. 6.Jarvis, I., Jarvis, K. E. (1985). Rare-Earth Element Geochemistry of Standard Sediments: A Study Using Inductively Coupled Plasma Spectrometry. Chemical Geology, 53, 335-344.	
Course Outcome:	1.To develop an ability to analyze marine sediment constituents.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 525
Title of the Course: Marine Ecology
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To understand the concepts related to marine habitats and their role in ecosystem function.	
Content:	**Module I** Marine ecosystems – pelagic and benthic, indiscriminate predation and area hypothesis, bio-turbation and turbidity currents, Deep sea biology – scheme of zonation, sampling, constraints, environmental factors, OMZ and food sources, adaptations, reproductive strategy, bioluminescence, night vision and mechanism of production, benthic community structure, diversity, hypothesis, Polar seas - physical and biological factors, sea ice communities, microbial food web, soft sediment communities, Hydrothermal vents and cold seep communities, deep sea sulfide metabolism, symbiotic associations, food web – vent communities, Marine food webs – role of pico and nano plankton, viruses and host specific interactions, nutrient dynamics, bacteria, heterotrophic flagellates, protozoans and their role in trophic transfer. **Module II** Harmful Algal Blooms (HAB), major outbreaks, concern, oceanographic and ecological systems with HAB, effects and losses, HAB phenomena – oceanographic processes, population dynamics, adaptations, life history strategies, mixo-trophy and life cycle, behavioral and morphological adaptations, bio-toxin production, physical, chemical and biological interactions, impact of HAB, brevetoxins, causative species, bloom initiation, formation, propagation, decomposition, prevention - alterations in nutrient input, fresh water flow, circulation, restriction of introductions, and control – Chemical, biological, flocculants, role of zooplankton, viruses, parasites, bacteria. **Module III** Fouling communities – biofilm, chemistry, EPS, quorum sensing, dispersal and adhesion mechanism in *Enteromorpha* and barnacle and fouling control, Introduces species - human caused global changes, invasions and extinctions, human health , and bio-invasion - anthropogenic input, range extensions, effect on life cycle and fish mortality, Benthic metabolism - benthic autotrophic processes, photochemical reactions, nutrient leaching, benthic production and	15 hrs. 15 hrs. 15 hrs.

	vertical stratification, chemical composition of sediments, predators in sediment communities.	
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings:	1.Michel J. Kaiser, Martin J. Attrill, Simon Jennings, and David Thomas (Editors), 2020, Marine Ecology - Processes, Systems, and Impact, (3rd Edition), Oxford University Press, UK. 2.Frances Dipper, R V TAIT, 1998, Elements of Marine Ecology, (4th Edition), Elsevier, Amsterdam, Netherlands. 3.James W. Nybakken and Mark D. Bertness, 2005, Marine Biology: An Ecological Approach, 6th Edition, –, Pearson/Benjamin Cummings, San Francisco. 4.Levinton, J. S., 1982, marine EcologyPrentice-Hall, Inc., Englewood Cliffs, N.J., USA.. 5.T. R. Parsons, M. Takahashi and B. Habgrave, 1984, Biological Oceanographic Processes, 3rd edition, Pergamon Press, Oxford. 330 pp. 6.J. E. G. Raymont, 1980, Plankton & Productivity in the Oceans, Volume 1: Phytoplankton, 2nd Edition, Elsevier, Amsterdam, Netherlands. 7.J. E. G. Raymont, 1983, Plankton & Productivity in the Oceans, Volume 2: Zooplankton,, 2nd Edition, Pergamon press, Oxford. 8.Carol Lalli, C. M. and Thimothy Parson, 1997, Biological Oceanography – An Introduction, (2nd edition) –, Elsevier Ltd., Amsterdam, Netherlands. 9.Valiela Evans, 1995, Marine Ecological Processes, Springer Verlag, New York. 10.Mann, K. H., 2000, Ecology of coastal waters: with implications for management, 2nd edition, Blackwell Science, New Jersey, USA.	
Course Outcomes:	1.To understand marine biological processes in different ecosystems. 2.To address marine ecological issues associated with HAB phenomenon. 3. To study sediment communities and processes related to sediment-water interface.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 526
Title of the Course: Marine Ecology Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objective:	To elucidate the methods of estimating water quality/ environmental parameters and the use of different techniques to address various issues in Marine Ecology.	
Content:	Estimation of primary production by using light and dark bottle method (6 hours; Reference 1) Estimation of chlorophyll and phaeo-pigments in seawater sample using a spectro-photometric method (6 hours; Reference 2) Estimation of total organic carbon in seawater and/ or sediment samples (6 hours; References 3, 4). Designing of an experimental set-up to study uptake of oxygen by fish in the laboratory (6 hours; Reference 5). Computation of species diversity (H', J and D) indices using the data of phytoplankton/ zooplankton analysis and their implications in ecological studies (6 hours; Reference 6).	30 hrs.
Pedagogy:	Laboratory techniques, designing of experiments, computations and data interpretation.	
References/ Readings:	1.Selvaraj, G.S.D. (2005). *Estimation of primary productivity (modified light and dark bottle oxygen method).* In G.J. Parayannilam (Ed.), *Mangrove ecosystems:A manual for the assessment of biodiversity* (pp. 199-200). CMFRI Special Publication No. 83, Kerala, India. 2.Aminot, A., Rey, F. (2001). Chlorophyll a: Determination by spectroscopic methods (pp. 17 pp). ICES Techniqnes in Marine Environmental Sciences. No. 30. 3.Dickson, A.G., Sabine, C.L., & Christian, J.R. (Eds.) (2007) *Guide to best practices for ocean CO_2 measurement.* Sidney, British Columbia, North Pacific Marine Science Organization, (pp. 191), (PICES Special Publication 3; IOCCP Report 8). DOI: https://doi.org/10.25607/OBP-1342 4.El Wakeel, S.K., Riley, J.P. (1957). Determination of organic carbon in the marine muds. *Journal Du ConseilIntrenational Pour L'exploration De La Mer*,*22*, 180–183. 5.Bolduc, M., Lamarre, S., Rioux, P. (2002). A simple and inexpensive apparatus for measuring fish metabolism. *Advances in Physiology Education26*(2), 129-132. 6.Begon, M., Mortimer, M. & Thompson, D. J. (Eds.) (1996). *Population ecology: A unified study of plants and animals* (3rd ed). Wiley-Blackwell.	
Course Outcome:	1. To analyze water/sediment quality and estimate productivity using standard methods.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 527
Title of the Course: Principles of Mineralogy and Geochemistry
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objectives:	This course addresses the concepts of crystal chemistry, mineralogy, geochemistry and isotope geology. Further it also provides an insight on the origin of the earth, distribution of elements, evolution of mineral and also to understand geological processes that are necessarily inaccessible to observe directly.	
Content:	**Module I** Crystal chemistry: Ionic radii, co-ordination of ions, Pauling's Rules, different types of chemical bonding, crystal growth, crystal defects, external and internal symmetry, XRD: powder and single crystal diffraction. Twinning, Polymorphism and pseudomorphism. Mineral stability and phase diagram, two component eutectic systems, incongruent melting, solid solution system, exsolution. **Module II** Mineralogy: Mineral evolution, Biological-mineralogical interactions, Medical mineralogy. Composition, structure, Chemistry and paragenesis of the mineral groups: Olivine, Pyroxene, Amphibole, Mica, Feldspar, Garnet, Sulphide, Sulphate, Carbonate and Oxides. Optical mineralogy: Study of isotropic and anisotropic minerals under convergent light. Working principles of XRD, ICPMS, Spectroscopy, SEM, X-ray tomography. **Module III** Geochemistry: Introduction and scope of geochemistry, geochemical classification of elements, distribution and behaviour of major, trace elements and REE in igneous, sedimentary and metamorphic processes and products. Introduction to isotope geochemistry: Elements of nuclear systematics, introduction to isotopes and their properties. Introduction to Meteorites, origin, composition, classification and mineral constituents of meteorites.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ tutorials/assignments/field study/discussion	
References/Readings	1.Deer, W. A., Howie, R. A., and Zussman, J. (1992). *An introduction to the rock-forming minerals.* 2nd ed. Harlow, Essex, England. New York, NY. Longman Scientific and Technical. 2.Klein, C., Hurlbut, C. S., and Dana, J. D. (1999). *Manual of mineralogy: (after James D. Dana)*. New York: J. Wiley. 3.Winchell, A. N. (1991). *Elements of optical mineralogy: An introduction to microscopic petrography*. New York. Wiley. 4.Nesse W. (2012*). Introduction to Optical Mineralogy.4th ed.* Oxford University Press 5.Kerr, P. F. (1977). *Optical mineralogy*. New York. McGraw-Hill	

	Book Co. 6.Mason B., and Moore C.B. (1982). *Principles of geochemistry*. 4th ed. Chichester John Wiley 7.Krauskopf, K. B., and Bird, D. K. (1995). *Introduction to geochemistry*. New York. McGraw-Hill 8.Klein, C., and Dutrow, B. (2007). *Manual of mineral science*. New York. John Wiley and sons ltd Mason, B., and Moore, C. B. (1982). *Principles of geochemistry*. New York. Wiley. 9.Walther, J. V. (2009). *Essentials of geochemistry*. Sudbury, Mass. Jones and Bartlett Publishers. 10.White, W. M. (2014). *Isotope Geochemistry*. Hoboken. Wiley. 11.Faure, G. (1986). *Principles of isotope geology. Second edition*. John Wiley and Sons Inc., New York, NY 12.Dyar, M. D., and Gunter, M. E. (2008). *Mineralogy and optical mineralogy*. Chantilly. Mineralogical Society of America.	
Course Outcomes:	1. Provide a comprehensive understanding about the origin of Earth. 2. To emphasize on elemental distribution and mantle processes. 3. To study mineral evolution.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 528
Title of the Course: Principles of Mineralogy and Geochemistry Practical
Number of Credits: 1
Effective from AY: 2022-23

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other university recognized as equivalent.	
Objectives:	1. This course deals with the megascopic and petrographic identification of minerals. 2. It also deals with the use of instruments (Spectrophotometer, flame photometer) for analyses of different chemical constituents in water/soil/rocks.	
Content:	Observing and recording properties of representative minerals in hand specimens (7 hours; Reference 1, 3). Observation and recording of optical properties of rock forming minerals (7 hours; Reference 1, 2, 3). Determination of different chemical constituents in water/soil/rock using flame photometer and spectrophotometer. Reading of plots/graphs (8 hours; Reference 4). Numerical problems on partition coefficient, calculation of isotope ratios (8 hours; Reference 1, 2, 3).	30 hrs.
Pedagogy:	Megascopic and microscopic identification of minerals/Demonstrations/Laboratory experiments/Plotting and Interpretations.	
References/Readings	1.Mackenzie, W. S. (2015). *Atlas of the rock-forming minerals in thin section*. Routledge. 2.Barker, A. J. (2017). *A key for identification of rock-forming minerals in thin section* 3.Deer, W. A., Howie, R. A., and Zussman, J. (1992). *An introduction to the rock-forming minerals.* 2nd ed. Harlow, Essex, England. New York, NY. Longman Scientific and Technical. 4.Khandpur, R. S. (2006). *Handbook of analytical instruments*. New York, N.Y. McGraw-Hill Education LL	
Course outcome:	1. The student will learn the technique to identify minerals using physical and optical properties.	

SEMESTER II

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 508
Title of the Course: Estuarine and Coastal Physical Oceanography
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To impart knowledge about the hydro-dynamics of coastal waters to enable design activities related to environmental impact assessment. To highlight issues confronting the coastal areas due to both anthropogenic and natural processes.	
Content:	**Module I** Definition of estuaries – Physical characteristics of estuaries – Classification on the basis of fluid dynamics principles – Tides and tidal currents in estuaries – Tide-producing forces – tidal analysis and prediction – Salinity intrusion – Estuarine circulation and mixing – Stratification and entrainment – Fronts in estuaries – *Khazonn* lands – Processes in lakes – Anthropogenic impacts. Ekman transport – Upwelling and downwelling – Waves: Kelvin and Rossby waves, Edge waves, Seiches, Internal Waves, Tides, Surface Waves, Tsunamis – Longshore currents – Rip currents – Erosion – Deposition **Module II** Tropical cyclones: Cyclone structure, generation, growth and decay – Temperature, pressure field and wind speed and direction – Impact of cyclone landfall – Storm surges, wind and precipitation impact – Cyclones in north Indian Ocean. Global warming and sea level change and its impact – Mitigation measures. **Module III** Equipment used for physical oceanographic studies: Mechanical bathythermograph (MBT), Expendable bathythermograph (XBT), Reversing thermometers, CTD, Current meter, Acoustic Doppler Current Profiler (ADCP), sonic anemometer, Autosal, Moorings. Equipment used for atmospheric studies: psychrometer, anemometer, radio sonde, sun-photometer, radiation meter, Automatic Weather Station (A.W.S.). Research vessels: O.R.V. Sagar Kanya, F.O.R.V. Sagar Sampada, R.V. Sindhu Sadhana.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments/ case-studies	
References/Readings:	1.Dronkers, J., & van Leussen, W. (1988). *Physical Processes in Estuaries.* Springer-Verlag. 2.Defant, A. (1960). Physical Oceanography (Volume 2). Oxford, U.K.: Pergamon Press. 3.Open University Course Team. (2000). *Waves, Tides and Shallow-Water Processes (Second Edition).*The Open University and	

	Butterworth-Heinemann. 4.Gade, H. G., Edward, A., & Svendsen, H. (1982). *Coastal Oceanography.* New York, London: Plenum Press. 5.Dyer, K. R., (1997). *Estuaries: A Physical Introduction (Second Edition).* Chichester, New York: John Wiley. 6.Tomczak, M., & Godfrey, J. S. (2001). Regional Oceanography: an Introduction. Online edition. https://www.geo.uni-bremen.de/~apau/dynamicclimate/course_materials_2015/Resources/tomczak_godfrey_1994.pdf 7.Asnani, G. C. (2005). *Tropical Meteorology (Revised Edition).* Pune, India: G. C. Asnani, Indian Institute of Tropical Meteorology. 8.Kennish, M. J. (2001). *Practical Handbook of Marine Science (Third Edition).*CRC Press. Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., 9.Okem, A., Rama, B. (2022). *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press. In Press. https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/ 10.Shukla, P. R., Skea, J., Slade, R., Al Khourdajie, A., van Diemen, R., McCollum, D., Pathak, M., Some, S., Vyas, P., Fradera, R., Belkacemi, M., Hasija, A., Lisboa, G., Luz, S., & Malley, J. (2022). *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, NY, USA: Cambridge University Press. doi: 10.1017/9781009157926 . https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/ 11.Sonak, S. M. (2014). *Khazan Ecosystems of Goa – Building on Indigenous Solutions to Cope with Global Environmental Change.* Dordrecht: Springer; d.o.i.: https://doi.org/10.1007/978-94-007-7202-1 de Sousa, S. N. *The Khaznam of Goa.* http://www.niobioinformatics.in/pdf/events/indianestuaries/dsouza.pdf	
Course Outcomes:	1. An ability to plan and execute studies related to coastal and estuarine ecosystem. 2. To create awareness about natural and anthropogenic pressures to coastal habitats. 3. Use of different equipments used for physical oceanographic and atmospheric studies.	

Name of the Programme: M. Sc.Marine Sciences
Course Code:MSC 509
Title of the Course: Estuarine and Coastal Physical Oceanography Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To delineate and identify regions of water-masses, most-efficient sound-channel and estimate ocean currents and measure atmospheric parameters.	
Content:	Identification of water masses and determination of stability of water column using T-S diagram (6 hours; References 1–4) Estimation of sound speed and determination of SOFAR channel in different parts of the world ocean (6 hours; References 1, 4) Analysis of wind stress over world ocean (3 hours; References 1–4 and 6) Computation and analysis of dynamic topography (6 hours; References 2, 3 and 5) Measurements of atmospheric pressure, humidity, minimum and maximum temperature, computation of absolute humidity, specific humidity – Mixing ratio (3 hours; References 6 and 7) Determination of cyclone intensity from satellite images using Dvorak technique (6 hours; References 8)	30 hrs.
Pedagogy:	Tutorials/ assignments/ practical/ field study	
References/ Readings:	1.Wright, J., & Colling, A. (1995). *Seawater: its composition, properties, and behavior (Second Edition)*. Pergamon Press, in association with the Open University. 2.Colling, A. (2001). *Ocean circulation* (Second Edition) (Vol. 3). Butterworth-Heinemann in association with The Open University. 3.Pond, S., & Pickard, G. L. (1983). *Introductory Dynamical Oceanography (Second Edition).* Oxford, New York, Toronto, Sydney, Paris, Frankfurt: Pergamon Press. 4.Kennish, M. J. (2001). *Practical Handbook of Marine Science (Third Edition).*CRC Press. 5.Fofonoff, N. P., & Millard Jr., R. C. (1983). Algorithms for the computation of fundamental properties of seawater. UNESCO Technical Papers in Marine Science 44, Endorsed by UNESCO/SCOR/ICES/IAPSO/ Joint Panel on Oceanographic Tables and Standards and SCOR Working Group 51; Place de Fontenoy, Paris, France: UNESCO. d.o.i.: https://doi.org/10.25607/OBP-1450 Ahrens, C. D. (1985). *Meteorology Today: An Introduction to Weather, Climate and the Environment (Second Edition).* St. Paul, Minnesota, U.S.A.: West Publishing. 6.Ackerman, S. A., & Knox, J. A. (2012). *Meteorology–Understanding the atmosphere (Third Edition).* Jones & Bartlett	

	Learning Velden, C., Harper, B., Wells, F. Beven, J. L., II, Zehr, R. Olander, T., Mayfield, M., Guard, C., Lander, M., Edson, R, Avila, L., Burton, A., Turk, M., Kikuchi, A., Christian, A. Caroff, P., & 7.McCrone, P. (2006). The Dvorak Tropical Cyclone Intensity Estimation Technique: A Satellite-Based Method that Has Endured for over 30 Years. *Bulletin of the American Meteorological Society, 87(9),* 1195–1210. d.o.i.: https://doi.org/10.1175/BAMS-87-9-1195	
Course Outcome:	1. An ability to study physical oceanographic processes.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 510
Title of the Course: Estuarine and Coastal Chemistry
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To understand the concepts about the chemistry of the estuarine environment related to the properties and interactions of the substances.	
Content:	**Module I** Estuary – a chemical perspective, Salinity distribution in estuaries, Classification based on geomorphology and tidal range, flushing time, mixing and diffusion dispersal of pollutants in estuaries and near shore areas – Conservative and non – conservative properties of dissolved constituents during estuarine mixing – Behaviour of dissolved oxygen and pH, Dissolved organic matter in estuaries – sources, sinks and general biogeochemistry. **Module II** Micro-nutrient elements (P, N and Si) in estuaries – Forms, distribution and cycle, N:P ratios – Stoichiometry of the uptake and regeneration of the nutrient elements and of oxygen, Biogeochemistry of P, N and Si in estuaries, Minor and trace metals in estuaries – metal ion species – behaviour. **Module III** Chemistry of surface microlayer – Origin, thickness and collection of surface material, properties of the surface microlayer, Chemistry of estuaries along east and west coast of India – water chemistry – surface sediment and core sediment chemistry - biochemistry, role of physico-chemical and biological factors in estuarine chemistry, Equipments and instruments used in chemical study.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/tutorials/assignments/self-study.	
References/ Readings:	1.Burton, J. D., Liss, P. S. (1976). Estuarine Chemistry. Academic Press. 2.Head, P. C. (1985). Practical Estuarine Chemistry. Cambridge University Press. 3.Olausson, E., Cato, I. (1980). Chemistry and Biogeochemistry of Estuaries. John Wiley & Sons. 4.Riley, J. P., Chester, R. (1978). Chemical Oceanography. Academic Press. 5.Dyer, K. R. (1986). Coastal and Estuarine Sediment Dynamics. Wiley. 6.Dyer, K. R. (1980). Estuarine Hydrography and Sedimentation. Cambridge University Press. 7.Hansell, D. A., Carlson, C. A. (2002). Biogeochemistry of Marine Dissolved Organic Matter. Academic Press. 8.Bianchi, T. S. (2007). Biogeochemistry of Estuaries. Oxford University Press.	
Course	1. A comprehensive understanding of the properties and interactions of the	

Outcomes:	substances present in the estuarine environment. 2. To gain knowledge on the key processes operating in the estuarine environment and importance of dissolved O_2, and pH. 3. To understand the nutrients cycling and air-water interactions in the estuarine environment.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 511
Title of the Course: Estuarine and Coastal Chemistry Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To demonstrate the experiment involving analytical chemistry of the seawater.	
Content:	1. Spectrophotometric determination of dissolved inorganic phosphate in estuarine water by ammonium molybdate – ascorbic acid method (6 hours; Reference 1) 2. Spectrophotometric determination of nitrite in estuarine water by sulphanilamide – diamine method (6 hours; References 1, 2) 3. Spectrophotometric determination of nitrate in estuarine water by reduction to nitrite using copper – coated cadmium reduction column (6 hours; Reference 1) 4. Spectrophotometric determination of ammonia in estuarine water by indophenol blue method (6 hours; References 1, 3) 5. Spectrophotometric determination of dissolved inorganic silicate in estuarine water by ammonium molybdate – ascorbic acid – oxalic acid method (6 hours; Reference 1)	30 hrs.
Pedagogy:	Laboratory experiments/ field studies	
References/ Readings:	1.Grasshoff, K., Ehrhardt, M., Kremling, K. (1983). Methods of Seawater Analysis. VerlagChemie, Weinheim. 2.Ewing, G. W. (1981). Instrumental Methods of Chemical Analysis. NY: McGraw-Hill. 3.Parsons, T. R., Maita, Y., Lalli, C. M. (1984). A Manual of Chemical and Biological Methods for Seawater Analysis. Oxford: Pergamon Press.	
Course Outcome:	1. To develop analytical skills to determine the concentrations of micro-nutrient elements (P, N and Si) in estuaries/ aqueous systems.	

Name of the Programme: M. Sc.Marine Sciences
Course Code:MSC 512
Title of the Course: Estuarine and Coastal Biology
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To provide an insight to carbon dioxide cycle in the estuarine and coastal environment with reference to anthropogenic inputs. Further, it deals with the estuarine and coastal ecosystem processes, including adaptations and fish migrations.	
Content:	**Module I** Productivity in coastal and estuarine waters, Carbon cycle - production and transformation, Inorganic carbon, carbon – carbonate system, DOC sources, aerobic environments, processes, losses of organic carbon, processes, decomposers, anoxic environments - Fermentation, sulfate reduction, Methanogenesis, DOC internal and external sources, Role of phytoplankton in carbon export. **Module II** Salt marsh ecosystem – species composition, distribution, nutrient dynamics, primary productivity and ecological processes and fate of salt marsh plant; Mangrove ecosystem species composition, distribution, adaptations, primary productivity, heterotrophic production, secondary communities and energy flow. Coral reef – types, calcification, nutrient dynamics, Nutrition in coral, benthic algae, role in calcification, total system function. Seagrass and seagrass beds – growth and reproduction, biodiversity and ecosystem benefits, habitat alteration, blue carbon, key functions, threats and conservation. **Module III** Secondary production and estuarine ecosystem function, Heterotrophic processes and pathways, Plankton, nekton and benthic communities, adaptations (buoyancy, locomotion and defense) in coastal and estuarine plankton and nekton population, Fish migrations biology and energetics, Symbiosis in marine environment.	15 hrs 15 hrs. 15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments/ self-study	

References/ Readings:	1.K. R. Dyer, John, 2012, Estuarine Ecology. 2nd Edition,Wiley and Sons, New Jersey, USA. James G. Wilson, 1988, The Biology of Estuarine Management, , Springer, London (UK). 2.Frances Dipper, R V TAIT, 1998, Elements of Marine Ecology, (4th Edition), Elsevier, Amsterdam, Netherlands. 3.P S Meadows; J I Campbell, 1988, An introduction to marine science, , Glasgow: Blackie; Halsted Press, New York. 4.N Balakrishnan Nair and D M Thampy, 1980, A textbook of marine ecology, Macmillan, New Delhi. John H S Blaxter, Frederick Russell, Maurice Yonge (Editors), 1982, Advances in Marine Biology, 1st Edition, Academic Press (Elsevier), USA. 5.James W. Nybakken and Mark D. Bertness, 2005, Marine Biology: An Ecological Approach, 6th Edition Marine biology: An ecological approach (6th ed), –M. D. Pearson/Benjamin Cummings, San Francisco. 6.Mann, K. H., 2000, Ecology of coastal waters: with implications for management, 2nd edition, Blackwell Science, New Jersey, USA. 7.Valiela Evans, 1995, Marine Ecological Processes, , Springer Verlag, New York.	
Course Outcomes:	1. Understanding of the processes related to the carbon cycle in the oceans. 2. To understand various processes influencing coastal habitats. 3. To study adaptations and different types of symbiotic relations among marine organisms.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 513
Title of the Course: Estuarine and Coastal Biology Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in Semester I	
Objective:	Identification of commonly occurring marine organisms using morphological features.	
Content:	Identification of mangroves, their lifecycle and few biological characteristics (4 hours; References 1, 2, 3) Identification of hard corals and a few biological characteristics (6 hours; References 4, 5) Identification of few commonly occurring teleosts (ray-finned fishes) and their biological characteristics (8 hours; References 6, 7, 8) Identification of brachyuran crabs using morphology and gonopod characteristics, sex determination and their biological importance (4 hours; Reference 9) Identification of prawns and shrimps using external characteristics, sex determination and biological aspects (4 hours; Reference 9) Morphometric measurements and meristic counts of the Indian Mackerel, *Rastrelliger kanagurta* (4 hours; Reference 10)	30 hrs.
Pedagogy:	Identification of sampling devices, marine flora and fauna	
References/ Readings:	1.Untawale, A.G. (1985). Mangroves of India: present status and multiple use practices, UNDP/UNESCO Regional Mangrove Project, pp 67. 2.Dhargalkar, V.K., D'Souza, R., Kavlekar, D.P., Untawale, A.G.(2014). *Mangroves of Goa.* Forest department, Government of Goa and Mangroves society of India, Goa, India. 3.Hogarth,P.J. (2015).*Thebiologyofmangrovesandseagrasses*.OxfordUniversitypress. De, K., Venkataraman, K., Ingole, B. 2019. The hard corals (Scleractinia) of India: a revised checklist. *Indian J Geo-Marine Science*, *40*(10):1651-1660. 4.Venkataraman, K., Satyanarayana, Ch., Alfred, J.R.B., Wolstenholme, J. (2003). *Handbook on hard corals of India*.Kolkata: Zoological Survey of India. FAO species identification guide for fishery purposes. The living marine resourcesof the Western Central Pacific*., 1999b* - Carpenter K.E. & Niem V. H., *Volume 4.Bony Fishes Part 2 (Mugilidae to Carangidae)*. (Food and Agricultural Organization, Rome), pp. 2069–2790. 5.FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific*., 2001a* - Carpenter	

	K. E. & Niem V. H. *Volume 5. Bony Fishes Part 3 (Menidae to Pomacentridae)*. (Food and Agricultural Organization, Rome), pp. 2791– 3380. 6.FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific*., 2001b* - Carpenter K. E. & Niem V. H., *Volume 6. Bony Fishes Part 4 (Labridae to Latimeriidae), estuarine crocodiles, sea turtles, sea snakes and marine mammals*. (Food and Agricultural Organization, Rome), pp. 3381– 4218. 7.FAO species identification guide for fishery purposes. The living marine resources of theWestern Central Pacific*, 1988b* - Carpenter K. E. & Niem V. H. *Volume 2. Cephalopods, crustaceans, holothurians and sharks*. (Food and Agricultural Organization, Rome), pp. 687– 1396. 8.Bhendarkar, M.P, Naik, S.D, Ramteke, M.H, Raut, S.M., Swain, S. (2014). Morphometric and Meristic studies of Indian Mackerel, *Rastrelliger kanagurta* (Cuvier, 1817) off Southern Coast of Maharashtra, India. *Ecology Environment and Conservation*, *20*(4), 1705– 1708.	
Course Outcome:	1. The course will provide an insight on morphological features of marine flora and fauna and their application in identification of commonly occurring species.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 514
Title of the Course: Estuarine and Coastal Geology
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To understand estuarine and coastal geology with respect to sub-divisions, morphological units and processes including sediment distribution and depositional environments.	
Content:	**Module I** Estuaries: Classification based on tide - geological classification and evolution – sub-environments in estuaries: mudflats, salt marsh, mangrove, salt pans - sediment source, transportation and deposition – bed and suspended sediment sampling and analysis – mineralogy and geochemistry of estuarine sediments. **Module II** Estuaries of the western coast of India. Metals and other pollutants – their seasonal variation andmetal variation with time in the mudflats and mangroves. Application of metals in paleo-monsoon, sea level changes and paleoenvironment. Health of estuaries - Impact of human activities on estuaries and restoration of estuaries. **Module III** Coasts: classification, types of coast with reference to Indian coast line – evolution of the Indian coast - global sea level changes: eustatic, tectonic and isostatic. Coastal signature of sea level changes. Coastal resources and coastal zone management, CRZ regulations and ICZM. Impact of floods, tsunamis and antropogenic interferences in coastal processes, coastal erosion, preparedness and precaution measures.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings:	1.Burton, J. D., &Liss, P. S. (1976). Estuarine chemistry. London: Academic Press. 2.E., H.. (2009). P. C. Head (ed.). 1985. Practical Estuarine Chemistry. A Handbook. x + 337 pp. Cambridge, London, New York, New Rochelle, Melbourne, Sydney: Cambridge University Press. 3.Riley, & Chester, R. (1976). Chemical oceanography. Vol.5 edited by J.P. Riley and R. Chester (2nd ed.). Academic Press. 4.Wright, J., Colling, A., & Park, D. (Eds.). (1999). Waves, tides and shallow-water processes (Vol. 4). Gulf Professional Publishing 5.Dyer, K. R. (1986). Coastal and estuarine sediment dynamics. Chichester: Wiley. 6.Dyer, K. R. (1986). Estuarine hydrography and sedimentation, John Wiley & Sons. 7.Komar, P. D. (2018). Beach processes and erosion–An introduction.	

	Handbook of coastal processes and erosion, 1-20. 8.Milliman, J. D., & Haq, B. U. (Eds.). (1996). Sea-level rise and coastal subsidence: Causes, consequences, and strategies (Vol. 2). Springer Science & Business Media. 9.Krauskopf, K. B., & Bird, D. K. (1967). Introduction to geochemistry (Vol. 721). New York: McGraw-Hill. 10Tait, R. V., & Dipper, F. (1998). Elements of marine ecology. Butterworth-Heinemann.. 11.Meadows, P. S., & Campbell, J. I. (1988). An introduction to marine science. Glasgow: Blackie. 12.Balakrishnan, N. N., & Thampy, D. M. (1980). A textbook of marine ecology. Delhi: Macmillan. 13.Pethick, J. S. (1984). An introduction to coastal geomorphology. Dept. of Geography, Univ. of Hull. Gotje, Wouter & Cleveringa, Jelmer & Steijn, Rob & Esselink, 14.Peter. (2007). Restoration of estuarine habitats. What determines success or failure?. 10.13140/2.1.3414.6081.
Course Outcomes:	1. Understanding geology of estuarine and coastal sedimentary environments, processes and evolution. 2. Ability to understand and reconstruct estuarine and coastal environments. 3. To understand coastal geomorphology and processes affecting coastal landforms.

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 515
Title of the Course: Estuarine and Coastal Geology Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To illustrate various methods involved in analysis of marine sediments, understand depositional environments and study of coastal geomorphological features	
Content:	Grain size analysis – sand, silt, clay using pipette method – estimation and interpretation – at least ten samples from a sediment core (12 hours; References 1, 5) Determination of organic carbon – at least ten samples from a sediment core (4 hours; References 1, 4, 6) Heavy mineral identification (4 hours; References 1, 2) Study of depositional environments (4 hours; References 1, 2) Study of coastal geomorphological features (Field work) (8 hours; Reference 7)	30 hrs.
Pedagogy:	Laboratory experiments / Computations / Plotting and Interpretations and analysis/ Field Visit	
References/ Readings:	1.Friedman, G. M., & Johnson, K. G. (1982). Exercises in sedimentology. New York: Wiley. 2.Lindholm, R. C. (1987). A practical approach to sedimentology. London: Allen &Unwin. 3.Babu, S. K. & Sinha, D. K. (1987): Sedimentary Petrology Practical, CBS Pub., N. Delhi. 4.Carver, R. E. (1971). Procedures in sedimentary petrology. New York: Wiley-Interscience. 5.V.K. Verma and Prasad C (1981). A text book of Sedimentary Petrology Intl., Book Distribution. 6.Griffith, J. C., 1967, Scientific Methods in Analysis of Sediments: McGraw-Hill, New York, NY. 7.Monroe, J. S., Wicander, R., & Hazlett, R. W. (2007). Physical geology: exploring the earth (Vol. 584). Belmont: Thomson Brooks/Cole.	
Course Outcome:	1. To develop skill for conduct of analysis of marine sediments and to understand coastal geomorphology.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 529
Title of the Course: Geophysical Fluid Dynamics
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To impart an insight into different scales of motion in fluids (which includes both atmosphere and ocean) and to understand them by applying basic theorems and laws of fluid dynamics.	
Content:	**Module I** Basic concepts: fluid continuum, fluid properties, ideal fluid, types of flows; Scales of motions; Importance of rotation and stratification; Distinction between atmosphere and oceans. Statics: pressure surface and body forces on a fluid element; fundamental equation of fluid statics: application to compressible and incompressible fluids, hydrostatic equation along the vertical, application to the atmosphere, units of measurement; Newtonian and non- Newtonian fluids; Coriolis force; rotating frame of reference. **Module II** Kinematics: Lagrangian and Eulerian methods; 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; Principles of Prandtl's mixing length theory; momentum budget; salt and moisture budget; summary of governing equations; Boussinesq approximation; typical flow patterns; stream function; divergence and vorticity in different co-ordinate systems; material, local and convective derivatives. Equation of continuity and its applications; non-viscous incompressible flow; Eulerian equations of motion; inertial and rotational frames of reference; irrotational flow; velocity potential; integration of the equations of motion; Bernoulli's theorem and its applications. **Module III** Circulation and vorticity; Stokes' theorem; Kelvin's theorem; Helmholtz's theorems; barotropic and baroclinic fluids; absolute and relative circulation; V. Bjerknes' circulation theorem and its interpretation; conservation of potential vorticity; Eddy coefficients; Important dimensionless numbers; turbulent diffusion; combination of advection and diffusion; geostrophic flow and vorticity dynamics; laminar flow of viscous incompressible fluids; turbulence in stratified flows; Reynolds number and dynamic similarity of flows; physical significance of Reynolds number; low and high Reynolds' number.	15 hrs. 15 hrs. 15 hrs.

Pedagogy:	Lectures/ tutorials/ assignments/ seminars
References/ Readings:	1.Cushman-Roisin, B., & Beckers, J.-M. (2009). *Introduction to Geophysical Fluid Dynamics– Physical and Numerical Aspects.* Academic Press 2.Modi, P. N., & Seth, S. M. (1985). *Hydraulics and Fluid Mechanics.* New Delhi: Standard Book House. 3.Yuan, S. W. (1969). *Foundation of Fluid Mechanics.* New Delhi: Prentice Hall. 4.Batchelor, G. K. (1967). *An Introduction to Fluid Mechanics.* U.K.: Cambridge University Press. 5.Lamb, H. (1975). *Hydrodynamics.* U.K.: Cambridge University Press. 6.Rathy, R. K. (1976). *Introduction to Fluid Mechanics.* Oxford and IBH Publishing Company, New Delhi. 7.Roll, H. U. (1965). Physics of the marine atmosphere. *International Geophysics Series*, Vol. *7*. [Ed.] J. van Miegham. London: Academic Press. 8.Gill, A. E. (1982). *Atmosphere- Ocean Dynamics.* International Geophysics Series, Volume 30. New York: Academic Press. 9.Vallis, G. K. (2009). *Atmospheric and Ocean Fluid Dynamics– Fundamentals and Large-Scale Circulation.* Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo: Cambridge University Press. 10.Pedlosky, J. (1987). *Geophysical Fluid Dynamics (Second Edition).* New York, U.S.A.: Springer.
Course Outcomes:	1. An ability to understand the basic geophysical fluid dynamic processes. 2. An ability to understand the various geophysical fluid dynamical numbers. 3. To understand the basics of fluid flow patterns.

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 530
Title of the Course: Geophysical Fluid Dynamics Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To acquaint with a hands-on-experience based on learnings in the theory. It involves field-based observations and numerical techniques.	
Content:	1. Kinematics analysis of wind and ocean current – Isotach and isogon analysis and construction of streamline patterns (5 hours; Reference 1) 2. Construction of trajectories of air parcels from successive synoptic charts (5 hours; Reference 1) 3. Computation of divergence and vorticity in horizontal flow (5 hours; Reference 2) 4. Construction of stream lines for simple types of flow (5 hours; Reference 2) 5. Analysis of physical oceanographic parameters of estuarine waters using data of conductivity temperature and depth (CTD) instrument (5 hours; References 1, 3) 6. Analysis of aerosol trajectory using HYSPLIT (HYbrid Single – Particle Lagrangian Integrated Trajectory) model. (5 hours; References 4, 5)	30 hrs.
Pedagogy:	Tutorials/ assignments/ practical/ field study	
References/ Readings:	1.Stewart, R. H. (2008). *Introduction to physical oceanography*. Robert H. Stewart. https://open.umn.edu/opentextbooks/textbooks/20 2.Guide to Wave Analysis and Forecasting. (2018). *World Meteorological Organization (WMO-No. 702).* ISBN 978-92-63-10702-2. www.wmo.int/pages/prog/amp/mmop/documents/WMO%20No%20702/WMO702.pdf ; https://library.wmo.int/doc_num.php?explnum_id=10979 3.Siedler, G., Griffies, S., Gould, J., & Church, J. (2013). *Ocean Circulation and Climate– A 21st Century Perspective.* Academic Press. HYSPLIT- Hybrid Single Particle Lagrangian integrated Trajectory Model, Air Resources Laboratory, http://www.arl.noaa.gov/ . 4.Draxler, R. R., & Hess, G. D. (2020). *Description of the Hysplit_4 Modelling System; NOAA Technical Memorandum ERL ARL- 224. 1997, (Revised 2020).* Silver Spring, Maryland, U.S.A.: Air Resources Laboratory. https://www.arl.noaa.gov/documents/reports/arl-224.pdf 5.Roll, H. U. (1965). Physics of the marine atmosphere. *International Geophysics Series*, Vol. *7*. [Ed.] J. van Miegham. London: Academic Press. 6.Gill, A. E. (1982). *Atmosphere- Ocean Dynamics.* International Geophysics Series, Volume 30. New York: Academic Press.	
Course outcome:	1. To develop an ability to analyse flow patterns and an awareness of HYSPLIT online tool.	

Name of the Programme: M. Sc.Marine Sciences
Course Code:MSC 531
Title of the Course: Marine Pollution
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To provide an insight on the type of pollutants, sources and impact on marine life. Also, to learn conservative (radioactive pollutants, trace metals and pesticides) and non-conservative pollutants (oil and other organic wastes). Quantification of pollutant through suitable indicator organisms and monitoring strategies.	
Content:	**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; Thames and Mersey estuary; Consequences of sludge dumping at sea with reference to Thames and Firth of Clyde. Sewage treatment: Primary, Secondary and Tertiary treatment processes. Solid waste pollution: Classification and disposal of solid wastes. Industrial pollution: sources, nature and their treatment processes with reference to wastes from paper and pulp and 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 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). The present status of coastal pollution in India and future strategies. 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** Indicator organisms: Criteria for selection of indicator organism: Quantification of pollution load, basic pre-requisites, response to	15 hrs. 15 hrs. 15 hrs.

	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. Monitoring strategies of marine pollution: Critical pathway approach and Mass balance approach. Standards in water quality: Assessment of pollution damage: The need, seriousness of damage, assessment of damage and problems of measuring impact.	
Pedagogy:	Lectures/ tutorials/ assignments/ self-study	
References/ Readings:	1.Riley J.P and Skirrow, G (1975). Chemical Oceanography(3) Riley J.P and Skirrow, G. (eds.), Academic press, New York. 2.Goldberg, E.D (1976). The health of the oceans. UNESCO Press. 3.Clark, R.B (1986). Marine Pollution. Oxford science Publications. 4.Phillips J.D.H (1980). Quantitative aquatic biological indicators Applied Science Publishers. 5.Sharma, B.K and Kaur, H. Krishna (1994). Thermal and radioactive pollution, Prakasham Mandir (pub) Meerut. 6.B. K and Kaur, H. Krishna (1994). Water Pollution, 1994 - Sharma Prakasham Mandir (pub), Meerut. 7.Chandler, K.A. (1985). Marine Offshore corrosion, Butter Worths (pub) London.	
Course Outcomes:	1. To understand the impact of various pollutants on marine ecosystems. 2. To create awareness to safeguard the marine environment through identification of factors responsible for causing marine pollution. 3. To suggest policy measures to prevent marine pollution.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 532
Title of the Course: Marine Pollution Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To analyze the concentration of various pollutants in the seawater and their effect on marine life including BOD and COD to assess the impact of organic pollution.	
Content:	Determination of dissolved oxygen in polluted waters. (5 hours; Reference 1) Determination of biochemical oxygen demand in polluted waters. 5 hours; Reference 1) Determination of chemical oxygen demand in polluted waters. (5 hours; Reference 2) Pre-concentration of water for estimation of trace metals by AAS (5 hours; References 5, 6, 7) Estimation of Cd in polluted waters and biological sample. (5 hours; References 5, 6, 7) Estimation of Cu in polluted waters and biological samples. (5 hours; References 5, 6, 7)	30 hrs.
Pedagogy:	Demonstations/ Lab experiments.	
References/ Readings:	1.Martin, D.F (1972). Marine Chemistry (01). Academic Press, London. 2.Rice, E.W and Bridgewater L. American (2012). Standard methods for the examination of water and waste water analysis (22nd edition), Public health association, Washington DC. 3.Grasskhoff, K, M (1983). Methods of Seawater analysis. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim. 4.Strickland, J.D.H, and Parsons, T.R (1972) A practical hand book of seawater analysis. Fisheries Board of Canada bulletin. (2nd edition). 5.Riley, J. P. and Skirrow, G (1975). Analytical chemistry of seawater, In Chemical Oceanography (03), Riley, J. P. and Skirrow, G (eds.). Academic Press, London. 6.Allen, S. E., Grimshaw, H. M., Parkinson, J. A., Quarmby, C. and Roberts, J. D. (1976). Chemical Analysis. In: Methods in plant Ecology, S. B. Chapman (eds.), Blackwell Scientific Publications, Oxford, Chapter 8.	
Course Outcome:	1. To apply the results of analyses of different pollutants to draw valid inferences affecting marine life.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 533
Title of the Course: Marine Microbial Ecology
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in Semester I	
Objective:	To provide basic information and concepts of marine microbiology and its importance to enable identification of microbes from marine environments.	
Content:	**Module I** Marine microbiology its importance and need; History of marine microbiology; Instruments and sampling methods; Sampling strategies and methods for assessment of microbial biodiversity; Microbial habitats and major types (producers, consumers, symbionts, etc.) in relation to their habitats; Characteristics of marine microbes; Distribution and abundance and their adaptations to pressure, depth, salt, temperature; Chemosynthesis and microbial heterotrophic metabolism. **Module II** Microbial role in cycling of N, P and S; Integrated effects of nutrient dynamics; Effect of ions of major and trace elements; Toxicity and mechanism of tolerance in marine microbes; Concept of microbial loop in relation to marine food web dynamics; Role of microorganisms in DOM production and consumption; Role of marine microbes in production of RDOC and sequestering of carbondioxide; Pollution indicator and pathogenic marine microbes. **Module III** Biochemical characterization of marine prokaryotes; Meta-genomic analysis; Principles and applications of TFF for microbial molecular analysis; Principles and methods of DNA/ RNA extraction, Principle and applications of PCR; GEL electrophoresis, DNA purification and visualization techniques; Bioinformatics for marine molecular analysis – principles of phylogenic tree, BLAST analysis, search tools; sequence data base; Application of different statistical test (Shannon – Wiener diversity index, Simpson index, species richness, Chao, ACE indices) for microbial diversity analysis.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments/ self-study	
References/ Readings:	1.Gasol, J. M. & Kirchman, D. L. (Eds.) (2018). *Microbial Ecology of the Oceans* (2nd ed). John Wiley & Sons. 2.Munn, C. (2020). *Marine Microbiology: Ecology & Applications* (3rd ed). CRC Press.. 3.Hunter-Cevera, J., Karl, D., Buckley, M. (2005). *Marine Microbial Diversity: The Key to Earth's Habitability*. This report is based on a colloquium, sponsored by the American Academy of Microbiology,	

	held April 8–10, 2005, in San Francisco, California. Washington (DC): American Society for Microbiology. 4.Meller, C. B., & Wheeler, P. A. (Eds.) (2012). Biological Oceanography (2nd ed), Wiley–Blackwell Publishers. 5.Oliver, J. D. (1982). Taxonomic scheme for the identification of marine bacteria. *Deep Sea Res*earch Part A. Oceanographic Research Papers *29*(6), 795–798. 6.Valiela, I. (1995). *Marine Ecological Processes* (2nd ed). Springer-Verlag, New York. 7.Belkin, S., & Colwell, R. R. (Eds.) (2005). *Ocean and Health: Pathogens in the marine Environment*. Springer–Verlag, NewYork. 8.Kennedy, J., Flemer, B., Jackson, S.A., Lejon, D. P. H., Morrissey, J. P., O'Gara, F., Dobson, A. D. W. (2010). Marine Metagenomics: New Tools for the Study and Exploitation of Marine Microbial Metabolism. *Marine drugs 8,* 608-628. 9.Lear, G., Dickie, I., Banks, J., Boyer, S., Buckley, H. et al. (2018). Methods for the extraction, storage, amplification and sequencing of DNA from environmental samples. *New Zealand Journal of Ecology42*(1): 10.	
Course Outcomes:	1. The student will develop and provide information on marine microbial ecology. 2. It will help in applications of classical and molecular methods to understand ecological processes. 3. To understand applications of bioinformatic tools for analysis of microbial diversity.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 534
Title of the Course: Marine Microbial Ecology Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I	
Objective:	To elucidate basic concepts and techniques applied in marine microbiology.	
Content:	Sterilization techniques, preparation of bacterial media - nutrient agar plates, nutrient broth & agar slants (6 hours; Reference 1). Method of sample collection (water) from marine environment (3 hours; Reference 2). Enumeration and isolation of heterotrophic bacteria, pathogenic organisms and/or fungal population from water and sediments with reference to physico-chemical conditions (6 hours; References 3, 4, 5). Isolation of pure cultures for microscopy: wet mounts (3 hours; Reference 4). Separation of mixed culture, isolation, maintenance and preservation of pure culture (4 hours; Reference 3). Staining of bacteria and cell morphology (2 hours; Reference 1). Characterization, biochemical tests and identification of marine bacteria (6 hours; Reference 1).	30 hrs.
Pedagogy:	Laboratory techniques/ practical/ demonstrations/ field studies.	
References/ Readings:	1.Bergey, D. H., Krieg N. R., & Holt, J. G. (1984). *Bergey's manual of systematic bacteriology (Vol. I)*. William & Wilkins, Baltimore. 2.Colwell, R. R. (1975). *Marine and estuarine microbiology laboratory manual*. University Park Press. 3.Zobell, C. E. (1946). *Marine microbiology, amonograph on hydrobacteriology*. Chronica Botánica Company, Waltham, Mass. 4.Harigan, W. F., &McCance, M. E. (1966). *Laboratory methods in microbiology.* Academic Press, London, New York. 5.Hurst, G. J., &Knudsen, G. R. (1997) *Manual of environmental microbiology*. ASM Press, Washington, D.C.	
Course Outcome:	1. The student will get acquainted with some of the basic methods and techniques to study microbiology of the marine environment.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 535
Title of the Course: Sedimentology
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	To learn sediment types and their distribution, concept of facies, heavy mineral zones, sedimentary depositional environments, sedimentary rocks and diagenesis.	
Content:	**Module I** Sedimentary rocks – Classification, properties, origin and importance – Sandstone, Limestone, mudstones and evaporites. Distribution and genesis of terrigenous, bio-genous, chemo-genous, volcanogenic, authigenic and extraterrestrial (cosmogenous) sediments in the world ocean – Rate of sedimentation in the oceans. **Module II** Concepts of sedimentary facies, facies construction and interpretation, factors controlling the nature and distribution of facies – Provenance – Heavy minerals, rock particles and clay minerals – Mineral stability – Goldich stability series, sediment maturity - X ray diffraction technique and its use in mineral and sediment study. **Module III** Sedimentary structures – Diagenesis: general considerations, terrigenousclastic sediments, carbonate sediments, evaporates and hydrocarbons. Sedimentary depositional environments – Aeolian, lacustrine, glacial desert, fluvial, coastal shallow marine and deep sea – Sedimentary and faunal markers of paleoenvironmental conditions. Biostratigraphy and its applications.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings:	1.Lisitzin, A. P., & Rodolfo, K. S. (1972). Sedimentation in the world ocean: with emphasis on the nature, distribution and behavior of marine suspensions. 2.Leeder, M. R. (1982). Sedimentology Process and Product, Departement of Earth Sciences, University of Leeds. 3.Pettijohn, F. J. (1957). Sedimentary rocks. New York: Harper. Krumbein, W. and Sloss, L. (1963) Stratigraphy and Sedimentation. W.H. Freeman and Co., San Francisco 4.Reading, H. G. (1986). Sedimentary Environments and facies 2nd edition. Blackwell Scientific Publications, Oxford, 6, 15. 5.Reineck, H. E., & Singh, I. B. (2012). Depositional sedimentary environments: with reference to terrigenousclastics. Springer Science & Business Media..	

	6.Blatt, H., Middleton, G. V., & Murray, R. C. (1972). Origin of sedimentary rocks. 7.Friedman, G. M., & Sanders, J. E. Principles of Sedimentology, 1978., John Wiley & Sons. 8.Carver, R. E. (1971). Procedures in sedimentary petrology. John Wiley & Sons Incorporated. 9.Allen, J. R. L. (1982) Sedimentary Structures: Their Character and Physical Basis. Vol. 1. Developments in Sedimentology. Elsevier, Amsterdam. 10.Allen, J. R. (1970). Physical processes of sedimentation. American Elsevier Pub. Co.. 11.Selley, R. C. (1970). Ancient sedimentary environments., Chapman & Hall. 12.Pettijohn, F. J., & Potter, P. E. (2012). Atlas and glossary of primary sedimentary structures. Springer Science & Business Media. 13.Pettijohn, F. J., Potter, P. E., & Siever, R. (1972). Sand and Sandstone. Springer-Verlag, Berlin Heidelberg New York.
Course Outcomes:	1. Understanding sediment processes, paleo-environments, formation. 2. Ability to reconstruct paleo-climate and paleo-environments. 3. To understand different sedimentary facies and provenance.

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 536
Title of the Course: Sedimentology Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Core courses offered in the Semester I.	
Objective:	This course introduces to experiments to analysis to understand depositional environments and processes and to demonstrate basic methods for analysis of marine sediments.	
Content:	Measurement of sphericity and roundness of sediment grains (6 hours; References 1, 2). Identification of sedimentary rocks (4 hours; References 3, 7). Identification of sedimentary structures (4 hours; References 3, 4). Study of sedimentary facies (4 hours; References 4, 5). Preparation of samples for X-ray diffraction analysis (4 hours; References 4, 6). XRD analysis for clay minerals, Clay mineral identification and estimation of Semiquantitative percentages and interpretation (4 hours; References 4, 6). Paleocurrent analysis (4 hours; Reference 4).	30 hrs.
Pedagogy:	Laboratory experiments/ Computations/ Plotting and interpretations and analysis.	
References/ Readings:	1.Friedman, G. M., & Johnson, K. G. (1982). Exercises in sedimentology. New York: Wiley. 2.Lindholm, R. C. (1987). A practical approach to sedimentology. London: Allen &Unwin. 3.Babu, S. K. & Sinha, D. K. (1987): Sedimentary Petrology Practical, CBS Pub., N. Delhi. 4.Carver, R. E. (1971). Procedures in sedimentary petrology. New York: Wiley-Interscience. 5.K. Verma & Prasad C. (1981). A text book of Sedimentary Petrology Intl., Book Distribution 6.Griffith, J. C., 1967, Scientific Methods in Analysis of Sediments: McGraw-Hill, New York, NY. 7.Moorhouse, W. W. (1959). The study of rocks in thin sections: by WW Moorhouse. Harper. 8.Read, H. H. (1970). Rutley's elements of mineralogy. London,UK: Thomas Murby& Co.	
Course Outcome:	1. To generate data and analyze to understand facies, paleo-current, sedimentary structure and depositional environments.	

SEMESTER III

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 600
Title of the Course: Computational Methods in Oceanography - I
Number of Credits: 02
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I (Marine Sciences).	
Objective:	To impart programming skills for applications in oceanography/Meteorology.	
Content:	**Module I** Introduction to python - Installing Python and writing your first program - Names and tokens - Blocks and indentation-Data Types in Python: Integers, Float, String - Variables in Python - Type Conversion in Python - Operators: Artithmetic Operators - Assignment Operators - Comparison Operators in Python - Logical Operators - Collection Data Types : List, Tuple, Dictionary files -sets- Input – Print. **Module II** Condition Statements : If Statement , Inline If - loops : For Loop, While Loop, Break, Continue,try, except - Strings in Python : Strip Method in Python String, String Methods : lower, upper and capitalize, casefold, center, count, endswith, encode, expandtabs and find, index isalnumisdigitisalpha method, isprintableisspaceistitle, isidentifierislower and isnumeric, isupper, join, lstrip and rstrip, partition, splitlines, startswith, swapcase, title and zfill - if,elif, else - Working with Files : Opening and Reading , Writing, Opening and Reading Text Files by Buffer Size , Opening, Reading and Writing Binary Files.	15 hrs. 15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments	
References /Readings:	1. Kuhlman D. (2021). A Python Book: Beginning Python, Advanced Python, and Python Exercises. Platypus Global Media 2.Brown M. C. (2018). Python: The Complete Reference. Osborne/McGraw Hill 3.Mark Summerfield(2010).Programming in Python 3: A Complete Introduction to the Python Language. Addison-Wesley Professional. 4.Mohbey K. M. and Bakariya Brijesh (2021). An Introduction to Python Programming: Using Python to Solve Complex Problems with a Burst of Machine Learning. BPB Publications. 5. Sheetal T. and Kumar Naveen (2017). Python Programming |A modular approach. Pearson	
Course Outcomes:	1. Acquire computational and programming knowledge to deal with large data sets and generate code. 2. To develop an ability to analyse, extract regional data from global ocean/ atmospheric data sets.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 601
Title of the Course: Computational Methods in Oceanography Practical
Number of Credits: 02
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I (Marine Sciences).	
Objective:	To impart programming skills applicable to oceanography/ meteorology.	
Content:	**Module I** 1. Programs illustrating use of Data Types in Python: Integers, Float, String, Variables in Python - Type Conversion in Python. (6 hrs.; Ref. 1-5) 2. Programs illustrating Operators: Artithmetic Operators - Assignment Operators - Comparison Operators in Python List, Tuple, Dictionary files -sets (4 hrs.; Ref. 1-5) 3. Programs illustrating reading/writing data from files. (4 hrs.; Ref. 1-5) 4. Programs illustrating List, Tuple, Dictionary files – sets(4 hrs.; Ref. 1-5) 5. Programs illustrating use of If Statement, Inline If, - Strings in Python (4 hrs.; Ref. 1-5). 6. Programs illustrating For Loop, While Loop, Break, Continue,try, except(4 hrs.; Ref. 1-5). **Module II** Programs illustrating Strings, Arrays (6 hrs.; Ref. 1, 2, 3, 4) Programs illustrating use of multi-dimensional arrays to generate monthly SST climatology for world ocean (12 hrs.; Ref. 1, 2, 3, 4) Programs illustrating computation of average southwest rainfall over India(6 hrs.; Ref. 1, 2, 3, 4) Programs illustrating computation of variability of SST at any given location over world ocean (6 hrs.; Ref. 1, 2, 3, 4).	30 hrs. 30 hrs
Pedagogy:	Lectures/ Tutorials/Practical	
References/ Readings:	1.Kuhlman D. (2021). A Python Book: Beginning Python, Advanced Python, and Python Exercises. Platypus Global Media 2.Brown M. C. (2018). Python: The Complete Reference. Osborne/McGraw Hill 3.Summerfield M. (2010).Programming in Python 3: A Complete Introduction to the Python Language. Addison-Wesley Professional. 4.Mohbey K. M. and Bakariya Brijesh (2021). An Introduction to Python Programming: Using Python to Solve Complex Problems with a Burst of Machine Learning. BPB Publications. 5. Sheetal T. and Kumar Naveen (2017). Python Programming |A modular approach. Pearson	
Course	1. Acquire basic programming techniques using PYTHON.	

Outcomes:	2. To apply programming techniques for application in oceanography/meteorology/climatology.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 602
Title of the Course: Computational Methods in Oceanography-II
Number of Credits: 02
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I (Marine Sciences).	
Objective:	To use statistical knowledge to estimate ocean/atmospheric parameters for application in oceanography/meteorology.	
Content:	**Module I** Descriptive statistics: population, sample – measures of central tendency: Arithmetic, Geometric and Harmonic means, Median and Mode. Measures of dispersion: Range - inter-quartile range, quartile deviation, coefficient of quartile deviation, mean deviation and standard deviation –variance, skewness, kurtosis. **Module II** Linear correlation, Karl - Pearson's coefficient of correlation, concurrent deviation method, method of least squares (regression) – regression equation. Introductory probability- Normal and binomial distribution – Inferential statistics: standard error – significance level – hypothesis testing: Student's t-test: test of significance for attributes, large samples and small samples and correlation coefficient. Z test, Ψ^2 (chi square) test, F test, Analysis of Variance.	15 hrs. 15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments	
References/ Readings:	1.Gupta, S. C. (2009). *Statistical Methods.* (Sixth Edition). Himalaya Publishing House. 2.Wilks, D. S. (2011). *Statistical Methods in Atmospheric Sciences.* (Second Edition). Academic Press. 3.Samchetr, D. C. and Kapoor, V. K. (1988). *Statistics: Theory Methods and Applications.* New Delhi: Sultan Chand and Sons. 4.Morrison, D. F. (1990). *Multivariate Statistical Methods.* Singapore: McGraw Hill Publ.	
Course Outcomes:	1. Acquire basic programming techniques using PYTHON. 2. To apply programming techniques for application in oceanography/meteorology/climatology.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 603
Title of the Course: Field Sampling
Number of Credits: 1
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I (Marine Sciences).	
Objective:	To plan and execute field sampling in oceanography.	
Content:	Cruise track, ship/ vessel/ human resource management in continuous observations – Instruments used in physical oceanography –research-ships and facilities on-board for physical oceanography and Meteorology. Selection of study area and sampling strategy, collection of water, sediments and biological resources (microbes, plankton, nekton, benthos), storage and fixatives used. Sampling techniques and equipments - seawater and sediments by using different oceanographic equipment. Pre-treatment of water in the field before analysis Sediment sample collection, processing and preservation.	15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments	
References/ Readings:	1.Stewart, R. H. (2008). *Introduction to physical oceanography*. Robert H. Stewart. 2.Thomson, R. E., & Emery, W. J. (2014). *Data analysis methods in physical oceanography* (Third Edition). Elsevier B. V. doi: https://doi.org/10.1016/C2010-0-66362-0 3.Pickard, G. L., & Emery, W. J. (2016). *Descriptive physical oceanography: An introduction.* Netherlands: Elsevier Science. Joseph, A. (2014). *Measuring ocean currents.* Elsevier. doi:https://doi.org/10.1016/C2011-0-05833-7 WMO. (2021) *Guidelines on Surface Station Data- Quality control and quality assurance for climate applications*. No-1269, WMO, Geneva. 4.Eisma, D., (1993). *Suspended matter in the aquatic environment*. Springer – Verlag. 5.State of Ohio Environmental Protection Agency. (2001). *Sediment sampling guide and methodologies*. (Second Edition). 6.Grasshoff K., Kremling K., Ehrhardt M., editors (1999). Methods of Seawater Analysis.(Third edition). Weinheim: Wiley-VCH.	
Course Outcome:	1. An understanding of sampling involved in oceanography.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 604
Title of the Course: Field Sampling Practical
Number of Credits: 1
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I (Marine Sciences).	
Objectives:	To design and conduct of field work associated with different aspects of Marine Sciences. To acquaint the students with the available methods and equipments used in sample collection and analysis.	
Content:	Preparation for inter-tidal and onboard sampling (2 hrs.; Ref. 1) Observation of wind and humidity parameters and analysis (4 hrs.; Ref. 5). Onboard collection of water, sediment and biological samples (8 hrs.; Ref. 1). Laboratory analysis of water (pH, DO, salinity). (5 hrs.; Ref. 2-4). Laboratory analysis of biological resources(microbes, phytoplankton and zooplankton). (5 hrs.; Ref. 2-4). Laboratory analysis of sediment (TOC). (4 hrs., Ref. 2-4). Report preparation and submission. (2 hrs.)	30 hrs.
Pedagogy:	Tutorials/ assignments/ practical/ field-study	
References/ Readings:	1.Cruise Planning. Scripps Institute of Oceanography. https://scripps.ucsd.edu/ships/planning 2.Grasshoff K., Kremling K., Ehrhardt M., editors (1999). Methods of Seawater Analysis.(Third edition). Weinheim: Wiley-VCH. 3.Loring, D. H. and Rantala, R. T. (1992). *Manual for Geochemical Analysis of Marine Sediments and Suspended Particulate Matter.* Earth Science Reviews, 32, 235-283. 4.Clark, M. R., Consalvey, M. and Rowden, A. A. (2016). *Biological Sampling in the Deep Sea.* Wiley Blackwell. 5.WMO. (2021). *Guidelines on Surface Station Data- Quality control and quality assurance for climate applications*. No-1269, WMO, Geneva.	
Course Outcome:	1. An understanding of field sampling, its planning and lab analysis.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 605
Title of the Course: Research Methodology – Physical Oceanography
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I (Marine Sciences).	
Objective:	To impart basic research methodology in physical oceanography.	
Content:	Data-sets used in physical oceanography, Metadata, Ferret/SURFER software, SDF/HDF/NC/ASCII formats, Understanding global/ regional gridded multi-dimensional data sets, handling missing values, extracting data of specific spatial and temporal extent, masking of data, Horizontal and vertical sections of Oceanographic properties.	15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments	
References/ Readings:	1.Thomson, R. E., & Emery, W. J. (2014). *Data analysis methods in physical oceanography (Third Edition).* Elsevier B. V. doi: https://doi.org/10.1016/C2010-0-66362-0 2.Tomczak, M., & Godfrey, J. S. (2001). *Regional Oceanography: an Introduction*. Online edition. https://www.geo.uni-bremen.de/~apau/dynamicclimate/course_materials_2015/Resources/tomczak_godfrey_1994.pdf 3.Stewart, R. H. (2008). *Introduction to physical oceanography*. Robert H. Stewart. https://open.umn.edu/opentextbooks/textbooks/20 PMEL, NOAA. Ferret software product of National Oceanographic and Atmospheric Administration's (NOAA) Pacific Marine Environmental Laboratory (PMEL). https://ferret.pmel.noaa.gov/Ferret/ 4.National Research Council. (1993). *Statistics and physical oceanography*. Washington D.C.: National Academies Press 5.Goddard, W., & Melville, S. (2001). *Research methodology: An introduction (Second Edition).* Lansdowne: Juta & Co. Ltd. ISBN: 9780702156601	
Course Outcome:	1. Understanding of research methodology in physical oceanography.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 606
Title of the Course: Research Methodology – Chemical Oceanography
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I (Marine Sciences).	
Objective:	To impart basic research methodology in chemical oceanography.	
Content:	Spectro-analytical methods: Photometry and Spectrophotometry, Fluorimetry, Flame photometry, Atomic absorption spectrophotometry, Flameless AAS and Inductively coupled plasma emission spectrometry; Chromatographic methods: Gas liquid and high performance liquid chromatography, principles and application to marine samples.	15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments/Self study.	
References/ Readings:	1.Vogel, A. I. (1978). *A text book of quantitative Inorganic*.(4th Edition). The English Language Book Society and Longman, New York. 2.Rice, E. W. and Bridgewater, L. (2012). *Standard Methods for the Examination of Water and Waste Water Analysis*. Washington DC: American Public Health Association. 3.Grasshoff K., Kremling K., Ehrhardt M., editors (1999). Methods of Seawater Analysis.(Third edition). Weinheim: Wiley-VCH. 4.Loring, D. H. and Rantala, R. T. (1992). *Manual for Geochemical Analysis of Marine Sediments and Suspended Particulate Matter.* Earth Science Reviews, 32, 235-283. 5.Day, R.A. and Underwood, A. L. (2001). *Quantitative analysis.* Prentice-Hall of India, New Delhi. 6.Ewing, G. W. (1981).*Instrumental methods of Chemical analysis*.(4th edition). Mc Graw Hill.	
Course Outcome:	1. Understanding of research methodology in chemical oceanography.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 607
Title of the Course: Research Methodology– Biological Oceanography
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I (Marine Sciences).	
Objective:	To impart basic research methodology in biological oceanography.	
Content:	Collection of biological (vertebrate and invertebrate) samples (inter-tidal and coastal), fixation, and preservation techniques for different groups of organisms. Analytical techniques used for estimation of different parameters (Chlorophyll-a and other pigments, dissolved and particulate organic carbon) of water. Morphometry and meristic counts, taxonomic tools for identification of various groups and sample preparation for DNA extract.	15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments/self-study.	
References/ Readings:	1.Eymann, J., Degreef, J., Häuser, C., Monje, J. C., Samyn Y. and Spiegel, V. D. (2010) *Sampling the marine realm* (In: *Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories + Monitoring* (ATBI+M) Chapter: ABC Taxa Volume 8, Editors, pp.273–307. 2.Hoedt, F. E., Choat, J. H., Cruz, J. J. and Collins, J. D. (2001).*Sample collection methods and practical considerations for introduced species' surveys at tropical ports*, CRC Reef Research Centre Technical Report No. 35. Townsville; CRC Reef Research Centre, 41 pp. 3.Wiebe, P. H., Bucklin, A. and Benfield, M. (2017).*Sampling, Preservation and Counting of Samples II: Zooplankton in Claudia*, Castellani and Martin Edwards (Eds.) *Marine Plankton: A practical guide to ecology, methodology, and taxonomy* by Oxford, online Edition, Oxford Academic, https://doi.org/10.1093/oso/9780199233267.003.0010.	
Course Outcome:	1. Understanding of research methodology in biological oceanography.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 608
Course Name: Research Methodology - Geological Oceanography
Number of Credits: 01 Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I (Marine Sciences).	
Objective:	To impart basic research methodology in geological oceanography.	
Content:	Suspended matter, grain size analysis, shear strength, organic carbon, nitrogen and phosphorus in sediment. Analytical methods for sediment geochemistry- XRF, Electron microprobe analysis, XRD (X-Rays, diffraction, components of X-ray diffractometer and X-ray safety), IRMS. Study of destructive and non-destructive foraminiferal paleo-climate proxies.	15 hrs.
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/Readings:	1.Friedman, G. M., and Johnson, K. G. (1982). *Exercises in sedimentology*, John Wiley and sons. 2.Griffiths, J. C. (1967). *Scientific method of analysis of sediments*, McGraw-Hill. 3.Hemleben, Ch., Spindler, M. and Anderson, O. R. (1989). *Modern planktonic foraminifera.*Springer New York, NY. 4.Henderson, M. G. (2002). *New oceanic proxies for paleoclimate.* Earth and Planetary Science Letters, 203,1-13. 5.Krauskopf, K. B. and Bird, D. K. (1995). *Introduction to geochemistry.* McGraw-Hill. 6.Lindholm, R. (1987). *A practical approach to sedimentology*. C. B. S. Publ. And Distr. 7.Rollinson, H. (2013). *Using geochemical data- evaluation, Presentation, interpretation.* Routledge. 8.Saraswati, P. K., Srinivasan, M. (2015). *Micropaleontology: Principles and Applications*. Germany: Springer International Publishing. 9.Saraswat, R. (2015). *Non-Destructive foraminiferal paleoclimatic proxies: A brief insight.* Proc. Indian Nat. Sci. Acad. 81, (2), 381-395.	
Course Outcome:	1. Understanding of research methodology in geological oceanography.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 621
Title of the Course: Remote Sensing and its Applications
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To provide a basic understanding of remote sensing, and some applications in physical oceanography and auxiliary disciplines.	
Content:	**Module I** Principles of Electromagnetic radiation, energy and matter interactions – Rayleigh scattering – Mie scattering, Non selective scattering – radiative transfer in the atmosphere – Stefan's law and Wien's displacement law – Zenith and azimuth angles. **Module II** Optical remote sensing – bio-optical properties of sea water – inherent and apparent optical properties – scattering – absorption-attenuation - diffuse attenuation – remote sensing reflectance – Case I and Case II waters – radiative transfer in the water column.Sun photometry – Beer-Lambert's law – spectral variation of aerosol optical thickness – atmospheric correction – interpretation of ocean colour. **Module III** Thermal infrared remote sensing – Thermal infrared properties – Atmospheric windows – Thermal radiation laws – Emissivity – sea surface temperature retrieval through IR sensors – Active and passive microwave remote sensing – Satellite altimetry of sea surface topography.Sensor characteristics of AVHRR, CZCS, SeaWiFS, MODIS, MSI, OCM-2 and FLEX – fundamentals of digital image processing – image rectification – image enhancement – linear stretching – supervised and unsupervised classification.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments	

References/ Readings:	1.Rees, W. G. (1990). *Physical Principles of Remote Sensing,* (1990). U.K.: Cambridge University Press. 2.Sabins Jr., F. F. (1987). *Remote Sensing: Principles and Interpretations (Second Edition)*. New York, U.S.A.: W. H. Freeman. 3.Robinson, I. S. (1985). *Satellite Oceanography*. Somerset, N.J., U.S.A.: John Wiley & Sons. 4.Narayan, L. R. A. (1999). *Remote Sensing and its Applications.* Hyderabad: Universities Press. 5.Mukherjee, S. (2004). *Textbook of Environmental Remote Sensing.* Delhi – Chennai – Jaipur – Mumbai – Patna – Bangalore – Bhopal – Chandigarh – Coimbatore – Cuttack – Guwahati – Hubli – Hyderabad – Lucknow – Madurai – Nagpur – Pune – Raipur – Siliguri – Thiruvananthapuram – Visakhapatnam : Macmillan India Limited. ISBN: 1403 92235 7. 6.Emery, W., & Camps, A. (2017). *Introduction to Satellite Remote Sensing: Atmosphere, Ocean, land and Cryosphere Applications.* Amsterdam – Oxford – Cambridge, Massachusetts, U.S.A.: Elsevier. ISBN: 978-0-12-809254-5. 7.Janssen, L. L. F., & Bakker, W. H. (2000). *Principles of Remote Sensing: An Introductory Textbook.* International Institute for Aerospace Survey and Earth Sciences. 8.Joseph, G. (2005). *Fundamentals of Remote Sensing (Second Edition).* Hyderabad: Universities Press.	
Course Outcomes:	1. An understanding of basics of remote sensing. 2. Applications of remote sensing to ocean science. 3. To understand basics of sensors used in remote sensing.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 622
Title of the Course: Remote Sensing and its Applications Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	Understanding of remote sensing and its applications in oceanography.	
Content:	1. Analysis of aerosol optical depth (A.O.D.) depth and estimation of atmospheric turbidity parameter and Angstrom exponent. (10 hrs, All references). 2. Chlorophyll-a concentration variability using satellite images (10 hrs, All references). 3. Application of satellite images to environmental issues. (10 hrs, All references).	30 hrs.
Pedagogy:	Practical/ tutorials/ assignments.	
References/Readings:	1.Rees, W. G. (1990). *Physical Principles of Remote Sensing,* (1990). U.K.: Cambridge University Press. 2.Sabins Jr., F. F. (1987). *Remote Sensing: Principles and Interpretations (Second Edition)*. New York, U.S.A.: W. H. Freeman. 3.Robinson, I. S. (1985). *Satellite Oceanography*. Somerset, N.J., U.S.A.: John Wiley & Sons. 4.Narayan, L. R. A. (1999). *Remote Sensing and its Applications.* Hyderabad: Universities Press. 5.Mukherjee, S. (2004). *Textbook of Environmental Remote Sensing.* Delhi – Chennai – Jaipur – Mumbai – Patna – Bangalore – Bhopal – Chandigarh – Coimbatore – Cuttack – Guwahati – Hubli – Hyderabad – Lucknow – Madurai – Nagpur – Pune – Raipur – Siliguri – Thiruvananthapuram – Visakhapatnam : Macmillan India Limited. ISBN: 1403 92235 6.Emery, W., & Camps, A. (2017). *Introduction to Satellite Remote Sensing: Atmosphere, Ocean, land and Cryosphere Applications.* Amsterdam – Oxford – Cambridge, Massachusetts, U.S.A.: Elsevier. ISBN: 978-0-12-809254-5. 7.Janssen, L. L. F., & Bakker, W. H. (2000). *Principles of Remote Sensing: An Introductory Textbook.* International Institute for Aerospace Survey and Earth Sciences. 8.Joseph, G. (2005). *Fundamentals of Remote Sensing (Second Edition).* Hyderabad: Universities Press.	
Course Outcome:	1. Understanding of basic applications of remote sensing in oceanography.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 623
Title of the Course: Dynamic Oceanography
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To understand the laws that govern ocean motion and formulate equations that describes this motion.	
Content:	**Module I** Basic physical laws used in oceanography; Classification of forces and motion; Equation of continuity: derivation of the equation of continuity of volume, application of the equation of continuity; static stability; double diffusion; Dynamic stability; Equation of Motion in Oceanography: form of equation of motion derivation of pressure term; Transforming from axes fixed in space to axes fixed in the rotating earth; Coriolis terms, Gravitation term.Equation for the mean or average motion; Non-linear terms in the equation of motion; Eddy viscosity. **Module II** Currents without friction; Vorticity: relative vorticity, planetary vorticity, absolute vorticity, potential vorticity; Geostrophic flow; Hydrostatic equilibrium; Geopotential; Geopotential surfaces and isobaric surfaces; Geostrophic methods for calculating relative velocity; Thermal wind equation; Relation between isobaric and isopycnal surfaces. **Module III** Currents with friction; The equation of motion with friction: Transport and upwelling; Bottom friction and shallow water effects; Ekman's theory of circulation, Sverdrup's solution for the wind driven circulation; Stommel's theory of circulation and Westward intensification; equatorial current system; Munk's equation and Boundary layer approach.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ tutorials/ assignments	
References/ Readings:	1.Pond, S. and Pickard, G. H. (1983). *Introductory Dynamical Oceanography.* U.K.: Pergamon Press. 2.Gill, A. (1982). Atmosphere – Ocean Dynamics. International Geophysics Series 30. San Diego, San Francisco, New York, Boston, London, Sydney, Tokyo: Academic Press. 3.Dijkstra, H. A. (2008). *Dynamical Oceanography.* Springer Science and Business Media 4.Vallis, G. K. (2017). *Atmospheric and Oceanic Fluid Dynamics.* Cambridge University Press.	

	5.Drijfout, S. S., Marshall, D. P., & Dijkstra, H. A. (2013). *Ocean Circulation and Climate.* Elsevier. 6.Long, J. A., & Wells, D. S. (2009). *Ocean Circulation and El Niño: New Research.* Nova Science Publishers Inc., United Kingdom 7.Huang, R. H. (2009). *Ocean Circulation: Wind-Driven and Thermohaline Processes.* Cambridge University Press. 8.Brown, E., Colling, A., Park, D., Philipps, J., Rothery, D., & Wright, J. (2001). *Ocean Circulation.* Elsevier Ltd.	
Course Outcomes:	1. Formulate equations that describe the ocean circulation and stability. 2. To understand the various kinds of vorticity. 3. To understand the development of the dynamical oceanographic theories.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 624
Title of the Course: Dynamic Oceanography Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	Application of theory for understanding of ocean circulation.	
Content:	Application of the equation of continuity to estimate ocean current velocity (6 hrs., All references). Estimate the static stability of water column using Buoyancy frequency (6 hrs., All references). Use of dynamic topography to study surface circulation (6 hrs., All references). Use of satellite altimeter data to study surface circulation (6 hrs., All references). Seasonality of Ekman transport along west coast of India (6 hrs., All references).	30 hrs.
Pedagogy:	Lectures/ tutorials/ assignments.	
References/ Readings:	1.Pond, S. and Pickard, G. H. (1983). *Introductory Dynamical Oceanography.* U.K.: Pergamon Press. 2.Gill, A. (1982). Atmosphere – Ocean Dynamics. International Geophysics Series 30. San Diego, San Francisco, New York, Boston, London, Sydney, Tokyo: Academic Press. 3.Dijkstra, H. A. (2008). *Dynamical Oceanography.* Springer Science and Business Media. 4.Vallis, G. K. (2017). *Atmospheric and Oceanic Fluid Dynamics.* Cambridge University Press. Drijfout, S. S., Marshall, D. P., & Dijkstra, H. A. (2013). *Ocean Circulation and Climate.* Elsevier. 5.Long, J. A., & Wells, D. S. (2009). *Ocean Circulation and El Niño: New Research.* Nova Science Publishers Inc., United Kingdom 6.Huang, R. H. (2009). *Ocean Circulation: Wind-Driven and Thermohaline Processes.* Cambridge University Press. 7.Brown, E., Colling, A., Park, D., Philipps, J., Rothery, D., & Wright, J. (2001). *Ocean Circulation.* Elsevier Ltd.	
Course Outcome:	1. Examine the stability of water column, describe surface circulation and coastal upwelling.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 625
Title of the Course: Analytical Chemistry of Seawater and Natural Products.
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To study different techniques used for extraction of various inorganic (fresh water, salt, bromine, calcium, magnesium and potassium) and organic chemicals (Agar, Carrageenan and Alginic acid)	
Content:	**Module I** General Errors, Accuracy and Precision. Filtration and Storage - Criteria of an ideal filtering medium - Glass fiber, membrane and Nucleopore filters. Storage for analysis of water for major elements, nutrients, dissolved phosphate, total phosphorous, nitrogen compounds silicates, and trace metals. Chemical separation methods: Pre-concentration methods: Co-precipitation, Co-crystallization, ion exchange and solvent extraction methods, their principles and applications. **Module II** Methods of desalination, Chemical recovery process - salt manufacture, Recovery of bromine from salt bittern, Dow process, Steaming out process for the manufacture of bromine. Recovery of magnesium, Dow process and IG-MEL process for the production of magnesium. Recovery of potassium from sea water, Balard and Niccoli Processes for the production of potassium from sea water. **Module III** Extraction of Agar, Alginates and Carrageenan from seaweeds - their structures, production, uses and toxicology. Extraction of marine drugs: Chemical and Pharmacological Aspects- Prostaglandins, Steroids, Terpenes and Nitrogenous compounds, Cephalosporins. Fish and Shellfish toxins, compounds from sponges.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments/ Self study.	
References/Readings:	1.Vogel, A. I. (1978). *A text book of quantitative Inorganic*. (4th Edition). The English Language Book Society and Longman, New York. 2.Rice, E. W. and Bridgewater, L. (2012). *Standard Methods for the Examination of Water and Waste Water Analysis*. Washington DC: American Public Health Association. 3.Grasshoff K., Kremling K., Ehrhardt M., editors (1999). Methods of Seawater Analysis.(Third edition). Weinheim: Wiley-VCH. 4.Day, R. A. and Underwood, A. L. (2001). *Quantitative analysis.* Prentice-Hall of India, New Delhi. 5.Ewing, G. W. (1981). *Instrumental methods of Chemical analysis*. (4th edition). Mc Graw Hill.	

	6.De, A. K. (1995). *Environmental Chemistry.* Wiley Eastern Limited and New age international limited, New Delhi. 7.Young, H. W. and Shimizu, Y. (1975). *Marine drugs: chemical and pharmaceutical aspects.* In: Riley, J. P. and Skirrow, G. *Chemical Oceanography*. London: Academic Press. 8.Scheuer, P.J (1983). *Marine natural products, Chemical and Biological prospective*. Academic Press, London.	
Course Outcomes:	1. Different techniques used for desalination of sea water. 2. To understand the processes in extraction of inorganic and organic chemicals from the sea. 3. To understand the potential of drugs from the sea.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 626
Title of the Course: Analytical Chemistry of Seawater Practical.
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To understand water's interactions with Earth's geologic materials, and to provide an insight into the impact of human activities on water bodies.	
Content:	Pre concentration of sea water for estimation of dissolved trace metals by AAS technique. (6 hrs.; Refs. 1, 2, 3, 4) Digestion of particulate matter for estimation of trace metals (6 hrs.; Ref. 4) Sediment digestion. (6 hrs.; Ref. 4) Estimation of dissolved and particulate Mn in seawater by Flame AAS method. (4 hrs.; Refs. 2, 3) Estimation of dissolved and particulate Fe in seawater by Flame AAS method (5 hrs.; Ref. 2, 3) Speciation of metals in sediments (Exchangeable, carbonate bound and total metal) (5 hrs.; Ref. 4)	30 hrs.
Pedagogy:	Lectures/ Demonstrations/ Lab experiments.	
References/ Readings:	1.Rice, E. W. and Bridgewater, L. (2012). *Standard Methods for the Examination of Water and Waste Water Analysis*. Washington DC: American Public Health Association. 2.Grasshoff K., Kremling K., Ehrhardt M., editors (1999). Methods of Seawater Analysis.(Third edition). Weinheim: Wiley-VCH. 3.Loring, D. H. and Rantala, R. T. (1992). *Manual for Geochemical Analysis of Marine Sediments and Suspended Particulate Matter.* Earth Science Reviews, 32, 235-283. 4.Riley, J. P. and Skirrow, G. (1975). *Chemical Oceanography*. Academic Press.	
Course Outcome:	1. Understanding the levels of trace metals in sea water for assessing the quality of seawater.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 627
Title of the Course: Metal Bio-availability, Bio-accumulation and Phyto-remediation
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To understand bioavailability, bioaccumulation and phyto-remediation.	
Content:	**Module I** Sources of metal to marine environment, factors regulating deposition. Definition and significance of speciation, bio-available and residual, driving factors for desorption from the bio-available fraction of the sediments - ionic composition – pH – Eh - organic matter degradation – metal toxicity assessment – SQUIRT – RAC. **Module II** Bioaccumulation – definition, mechanisms of accumulation in biota - Bioaccumulation factor (BAF) - concept of Bio-concentration – Bio-concentration factor (BCA) - harmful effects of bioaccumulation of metals on biota – Bio-magnification in trophic levels – risk to human health. Arsenic bioaccumulation in Sundarban Mangrove Wetland – a case study. **Module III** Metal accumulation in mangroves, phyto-remediation,techniques and applications of mangrove species (Phyto-extraction, Rhizo-filtration, phyto-volatilization, phyto-stabilization, phyto-degradation, Rhizo-degradation/Phyto-stimulation). Translocation Factor. Advantages and disadvantages of Phyto-remediation.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings:	1.Sarkar, S. K. (2018). *Trace metals in a tropical mangrove wetland.* Springer. 2.Adriano, D.C. (2001). *Trace elements in terrestrial environments.* Springer. 3.Neff, J. M. (2002). *Bioaccumulation in marine organisms.* Elsevier. 4.Hogarth, P. J. (2015). *The biology of mangroves and seagrasses.* Oxford University Press. 5.Tessier, A., Campbell, P. G. C. and Bisson, M. (1979). *Sequential extraction procedure for the speciation of particulate trace metals.* Analytical Chemistry, 51, 844–851.	
Course Outcomes:	1. To understand the bioavailability of metals in sediments. 2. Understanding of accumulation of metals by biota and mangroves. 3. Knowledge of application of mangroves in remediation of metal pollution.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 628
Title of the Course: Metal Bioavailability, Bioaccumulation and Phyto-remediation Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To determine metal concentration in sediments, macro-fauna, mangroves and remediation potential of mangroves.	
Content:	Digestion and chemical speciation of metals in sediments (Exchangeable, carbonate, Fe-Mn oxide, organic/sulphide and residual bound metals) (5 hrs.; Ref. 3, 4, 5) Estimation of Mn, Co, Ni in sediments by flame AAS method (5 hrs.; Ref. 1, 2, 3, 4, 5) Digestion and estimation of Mn, Co, Ni in tissues of biota (10 hrs.; Ref. 5, 6, 7) Digestion and estimation of Mn, Co, Ni in mangrove tissues for (10 hrs.; Ref. 5, 8, 9)	30 hrs.
Pedagogy:	Field studies/ Laboratory experiments / Interpretations	
References/ Readings:	1.Grasshoff K., Kremling K., Ehrhardt M., editors (1999). Methods of Seawater Analysis.(Third edition). Weinheim: Wiley-VCH. 2.Loring, D. H. and Rantala, R. T. (1992). *Manual for Geochemical Analysis of Marine Sediments and Suspended Particulate Matter.* Earth Science Reviews, 32, 235-283. 3.Tessier, A., Campbell, P. G. C. and Bisson, M. (1979). *Sequential extraction procedure for the speciation of particulate trace metals.* Analytical Chemistry, 51, 844-851. 4.Sarkar, S. K. (2018). *Trace metals in a tropical mangrove wetland.* Springer. 5.Ferreira, G. A., Machado, A. L. S. and Zalmin, I. R. (2004). *Temporal and spatial variation on heavy metal concentrations in the bivalve Pernaperna (Linnaeus, 1758) on the northern coast of Rio de Janeiro state, Brazil.* Brazilian Archives of Biology and Technology, 47, 319-327. 6.Yuzereroglu, T. A., Gok, G., Cogun, H. Y., Firat, O., Aslanyavrusu, S., Maruldali, O. and Kargin, F. (2010).*Heavy metals in Patella caerulea (mollusca, gastropoda) in polluted and non-polluted areas from the Iskenderun Gulf (Mediterranean Turkey).* Environmental Monitoring and Assessment, 167, 257-264. 7.Nath, B., Birch, G. and Chaudhuri, P. (2014).*Assessment of sediment quality in Avicennia marina-dominated embayments of Sydney Estuary: The potential use of pneumatophore (aerial roots) as a bio-indicator of trace metal contamination.* Science of the Total Environment, 472, 1010-1022.	

	8.MacFarlane, G. R. and Burchett, M. D. (2002). *Toxicity, growth and accumulation relationships of copper lead and zinc in the grey mangrove Avicennia marina (Forsk.) Vierh.* Marine Environmental Research, 54, 65-84.	
Course Outcome:	1. To understand bioavailability, bioaccumulation of metals and phyto-remediation process.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 629
Title of the Course: Marine Biodiversity
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objectives:	1. Understand the basic concepts of biodiversity. 2. To assess impacts of global warming and climate change on marine biodiversity.	
Content:	**Module I** Biodiversity, definition, concept, types; Biodiversity measurements - taxic, phylo-genetic and molecular approaches; Intra-specific Genetic variance and factors affecting, biodiversity and intra-specific variations, dominance and over-dominance hypothesis, adaptive polymorphism, Genetic variations, loss and increase. **Module II** Marine Biodiversity and ecosystem functions, competition, predation and heterogeneity as biodiversity determinants; ecosystem approach, functions and keystone species, engineer organisms, diversity-stability, rivet, drivers and passenger, idiosyncratic hypothesis, co-operative relations, top down and bottom up theories, cascade effect, dynamics of biological diversity, conceptual models, hypothesis proposed in deep sea biodiversity. **Module III** Semi-intensive shrimp culture and mangroves, environmental costs, problems associated with conservation of mangroves and shrimp culture, banned fishing practices, coastal tourism, Biodiversity conservation - corals, turtles, dugong, holothurians and shark, Biological diversity Act, sanctuaries, marine parks, protected areas and marine biosphere reserves of India - Bhitarkanika wildlife sanctuary, Gulf of Kachch Marine National Park and Sanctuary, Gulf of Mannar biosphere reserve, Wandoor Marine National Park.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments/ Self-study.	
References/ Readings:	1. Hiscock, K. (2014).*Marine Biodiversity Conservation: A practical approach*. (First Edition).London: Routledge. Queiroga, H., Cunha, M.R., Cunha, A., Moreira, Q. V., Rodrigues, A. 2.M., Serodio, J. and Warwick, R. M. (2007).*Marine Biodiversity: Patterns, processes, assessment, threats, management conservation*. Springer science and business media. 3.Harding, S. and Cousins N. (2022). *Review of the Impacts of*	

	Anthropogenic Underwater Noise on Marine Biodiversity and Approaches to Manage and Mitigate them. Technical Series No. 99. Secretariat of the Convention on Biological Diversity, Montreal. 4.Garcia, S.M. and Rice, J. (2020). *Assessing Progress towards Aichi Biodiversity Target 6 on Sustainable Marine Fisheries*. Technical Series No. 87. Secretariat of the Convention on Biological Diversity, Montreal. 5.Kailash C., C. Raghunathan and T. Mondal. (2017).*Glimpses of Coastal and Marine Biodiversity of India.*Zoological Survey of India, Kolkata, India. 6.Venkataraman K, Raghunathan C, Raghuraman R, Sreeraj CR. (2012).*Marine biodiversity in India*, Zoological Survey of India, Kolkata, India. 7.Secretariat of the Convention on Biological Diversity (2016) *Ecologically or Biologically Significant Marine Areas (EBSAs). Special places in the world's oceans.* Volume 3: Southern Indian Ocean. 8.Vandana Shiva (1994). *Biodiversity Conservation*. Publication of Indian National Trust for Art and Cultural Heritage, New Delhi.	
Course Outcomes:	1. Provide a holistic view of the Marine Biodiversity and processes that control distribution of aquatic life. 2. To understand the impact of coastal aquaculture on marine biodiversity. 3. To create awareness about environmental Laws and Acts towards management of marine habitats.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 630
Title of the Course: Marine Biodiversity Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the Course:	Students who have undergone M.Sc. Part I.	
Objective:	To acquaint with methods involved in assessing marine biodiversity and marine census.	
Content:	1. Photo documentation of marine species (6 hrs; Ref. 1, 2). 2. Biogeography of plankton, nekton and benthicorganisms (12 hrs.; Ref. 3, 4) 3. Marine Biodiversity through the World Register of Marine Species (WoRMS, COML, CedMAR) and related databases (12 hrs; Ref. 5, 6).	30 hrs.
Pedagogy:	Tutorials/ Assignments/ Practical/ Field study.	
References/ Readings:	1.Borda C., Popescu S. and El Mahdy J. C. (2014). *Marine Species Identification by Underwater Photography*. ProEnvironment,7, 59-63. 2.Dumas, P., Bertaud, A., Peignon, C., Léopold, M. and Pelletier, D. (2009). *A "quick and clean" photographic method for the description of coral reef habitats*. *Journal of Experimental Marine Biology and Ecology, 368*, 161-168. 3.Longhurst, A. R. (2007). *Ecological Geography of the Sea.* Academic Press. 4.Beaugrand, G. (2017). *Plankton Biodiversity and Biogeography.* In: C. Castellani and M. Edwards (Eds.). *Marine Plankton: A practical guide to ecology, methodology, and taxonomy* (First Edition).Oxford: Oxford University Press. 5.Costello, M. J., Bouchet, P., Boxshall, G., Fauchald, K., Gordon, D., Hoeksema, B. W., et al. (2013). *Global Coordination and Standardisation in Marine Biodiversity through the World Register of Marine Species (WoRMS) and Related Databases.* PLoS ONE 8(1): e51629. 6.Vandepitte, L., Vanhoorne, B., Decock, W., Vranken, S., Lanssens, T., Dekeyzer, S., et al. (2018). *A decade of the World Register of Marine Species – General insights and experiences from the Data Management Team: Where are we, what have we learned and how can we continue?*PLoS ONE 13(4), e0194599.	
Course outcome:	1. The students will be well versed with methods involved in cataloguing of marine organisms.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 631
Title of the Course: Aquaculture
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objectives:	This course focuses on the provision of basic concepts of farming of aquatic organisms, national and international status. The course educates students to learn different methods of culture, involving preparation of pond to harvesting.	
Content:	**Module I** Principles of aquaculture, history of aquaculture, global scenario, status and prospects of coastal aquaculture in India, traditional aquaculture practices, basic considerations, site selection, water quality management, species selection, feasibility and technique applied for mussel, pearl oyster, fish, lobster and seaweed culture practices. **Module II** Shrimp aquaculture, types of culture practices, traditional, modified traditional, extensive, critical requirements, site selection and pond preparation, selection of candidate species, brood stock procurement, hatchery production and management, nutrition, live feed culture and formulated feed preparation, water quality management in hatchery. **Module III** Reproduction, induced maturation by eye stalk ablation, role of X-organ, sinus gland system, status and prospects of brood stock, domestication and genetic improvement, shrimp diseases, pathology and parasitological, prophylactic and therapeutic measures, Coastal Aquaculture Act, 2005.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments/ Self-study	
References/Readings:	1.Bardach, J.E., Ryther J.H. and McLarney, M.O. (1972).*Aquaculture: the farming and husbandry of freshwater and marine organisms.* New York: Wiley-Interscience. 2.Black, K. D. (2000). *Environmental impacts of aquaculture.* Boca Raton, Fl., U.S.A.: CRC Press. 3.Kinne, O. (1983). *Diseases of marine animals.* Vol. 2. Introduction: Bivalvia to Scaphopoda. Hamburg:BiologischeAnstalt Helgoland. 4.Jhingran,V.G. (1991). *Fish and Fisheries of India.* Hindustan Publishing Corporation (India), New Delhi. 5.Lucas J. S., Southgate P. C., and Tucker C. S. (2019). *Aquaculture: Farming Aquatic Animals and Plants.*(Third Edition). Wiley-Blackwell. 6.McVey, J.P. (1993). *CRC handbook of mariculture*. Vol. 1. Crustacean aquaculture. (Second Edition). Boca Raton, Fl., U.S.A.: CRC Press. 7.Parker, R. (2011). *Aquaculture Science*. (Third Edition).Cengage Learning.	

	8.Paulraj, R. (1997). *Hand book on Aquafarming: Aquaculture Feed.* Manual. MPEDA, Cochin. 9.Pillay, T. V. R., Kutty, M. N. (2005). Aquaculture: Principles and Practices. (Second Edition). Blackwell Publishing Ltd. 10.Stickney, R. R. (2016). *Aquaculture: An Introductory Text.* (Third Edition).CABI Publishing.	
Course Outcomes:	1. To understand the basic principles involved in aquaculture practices. 2. To understand traditional management involved in shrimp and fish culture. 3. To understand shrimp hatchery management.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 632
Title of the Course: Aquaculture Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	This course aims to identify cultivable species and understand their reproductive biology.	
Content:	Methods of estimation of dissolved oxygen, BOD, suspended solids, particulate organic carbon and ammonia (15 hrs.; Ref. 1, 2, 3, 4) Identification of cultivable shrimps, mussels, oysters, fish, crabs and sea weeds (9 hrs., Ref. 5) Identification of larval stages of shrimp of commercial importance (4 hrs.; Ref. 6). Reproductive system of shrimp (2 hrs.; Ref.7).	30 hrs.
Pedagogy:	Laboratory analysis and identification	
References/ Readings:	1.Martin, D.F. (1972). *Marine Chemistry*. (Second Edition). M. Dekker (Ed.). New York. 2.Rice, E. W. and Bridgewater, L. (2012). *Standard Methods for the Examination of Water and Waste Water Analysis*. Washington DC: American Public Health Association. 3.Grasshoff K., Kremling K., Ehrhardt M., editors (1999). Methods of Seawater Analysis.(Third edition). Weinheim: Wiley-VCH. 4.Parsons, T. R., Maita, Y. and Lalli, C. M. (1984). *A Manual of Chemical and Biological Methods for Seawater Analysis*. Oxford: Pergamon Press. 5.Carpenter, K.E. & Niem, V.H. (1988). *FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, Vol. 2.Cephalopods,crustaceans, holothurians and sharks*. (Food and Agricultural Organization, Rome), pp. 687-1396. 6.Motoh, H. (1985). *Biology and ecology of Penaeus monodon*. In: Taki Y., Primavera J. H. and Llobrera J. A. (Eds.). Proceedings of the First International Conference on the Culture of Penaeid Prawns/Shrimps, 4-7 December 1984, Iloilo City, Philippines (pp. 27-36). Iloilo City, Philippines: Aquaculture Department, Southeast Asian Fisheries Development Center. 7.McVey, J. P. (1993). *CRC handbook of mariculture.* Vol. 1. Crustacean aquaculture. (Second Edition). Boca Raton, Fl., U.S.A.: CRC Press.	
Course Outcome:	1. Understand various biological aspects of cultivable species.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 633
Title of the Course: Tectonics, Geophysics and Structural Geology
Number of Credits: 03
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To impart an understanding of tectonics, geophysical methods and structural Geology.	
Content:	**Module I** Earth Quakes - classification, magnitude, epi-centre, recording - seismographs, shadow zone, earth quake waves, Elastic Rebound Theory. Volcanoes – types, volcanic products, volcanic land forms, central and fissure eruptions. Mountains and mountain chains. Structural Geology: Dip and stike, Folds, parts of fold, nomenclature and types, anticlinorium, synclinorium, open and close folds dome and basin. Rocks: classification - igneous, sedimentary, metamorphic and their properties. **Module II** Principles of geophysical methods: Gravity, magnetic and seismic – Elucidation of the structure of the earth using seismic model. Instruments used in marine geophysics – Gravimeter, magnetometer for marine studies, acoustic system techniques, echosounder (single and multi-beam), side scan sonar and sparker. Hydrography – position fixing, depth measurement and seabed mapping technique, hydrographic chart. **Module III** Computation plotting and interpretation of gravity and magnetic variations, identification of anomalies and interpretation of the data set. Computation of depth of ore body using half anomaly method. Gravity and magnetic observations and corrections, identification of anomalies and interpretation of the data set. Computation of depth of a single pole using half anomaly and peter's slope methods. Computation and interpretation of seismic data by reflection and refraction methods. Seismic profiles, sections and their interpretation, applications of geophysical methods in offshore exploration for oil, natural gas and other minerals.	15 hrs. 15 hrs. 15 hrs.
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings:	1.Thurman, H. V. (1988). *Introductory oceanography* (5th Edition), Columbus Merrill Publ. Co, Ohio. 2.Kennet, J. P. (1982). *Marine Geology*. Englewood Cliffs, N. J.: Prentice Hall Inc. 3.Namowitz, S. N. and Spaulding, N. E. (1985). *Earth Science*.D. C. Heath and Company.	

	4.Dobrin, M. B. (1976). *Principles of Geophysical Prospecting*.Mc. Graw Hill. 5.Nettleton, L. L. (1976). *Geophysical Prospecting for Oil.* Mc. Graw Hill. 6.Sheriff, R. E. and Geldant, L. P. (1983). *Exploration Seismology*. U.K: Cambridge Univ. Press. 7.Bath, B. M. (1974).*Spectral analysis in geophysics* (Developments in Solid Earth Geophysics).Elsevier. 8.Evenden, B. S., Stone, D. R. and Anstey, G. B. (1972). *Seismic Prospecting Instruments*. Berlin.	
Course Outcomes:	1. To understand tectonic evolution of the Earth. 2. To study geophysical methods in marine exploration. 3. To study structural geology concepts and applications.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 634
Title of the Course: Tectonics, Geophysics and Structural Geology Practical
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objectives	To understand the seismic profiles - volcanoes and earthquakes. Classification of rocks.	
Content	Interpretation of seismic refraction and seismic reflection data. (4 hrs.; Reference 1,8,9) Marking of plate boundaries, Hotspots/mantle plumes and volcanoes on world map and preparation of informative report. (4 hrs.; Reference 3) Completion of outcrop (4 hrs.; Reference 4,6,7) Preparation and interpretation of geological maps and sections, Structural problems concerning economic deposits. (4 hrs.; Reference 4,6,7) Drawing and interpretation of Rose diagram. (4 hrs.; Reference 4,6,7) Megascopic study of common Igneous and metamorphic rocks(10 hrs.; Reference 1,2,5)	30 hrs.
Pedagogy	Laboratory experiments, identification and interpretations.	
References/ Readings:	1.Best, M. G. and Christainsen, E. H. (2000). *Igneous Petrology*. (2nd Edition), Wiley–Blackwell. 2.Best, M. G. (1986). *Igneous and metamorphic petrology*. CBS. 3.Condie, K. C. (1989). *Plate tectonics and crustal evolution*. Pergamon Press. 4.Davis, G.H. and Reynolds, S. J. (1996). *Structural Geology of rocks and regions.* John Wiley and Sons. 5.Ehlers, E. G. (1999). *Petrology: Igneous, Sedimentary and Metamorphic.* CBS. 6.Marshak, S., and Mitra, G. (1988). *Basic methods of Structural geology.* Prentice Hall. 7.Rowland, S.M., Duebendorfer, E. and Schiefelbein, I. M. (2007). *Structural analysis and synthesis: a laboratory course in structural geology.* Blackwell Pub. Sharma, P. V. (1986). *Geophysical methods in geology*. Elsevier. 8.William, L. (1997). *Fundamentals of geophysics*. Cambridge University Press.	
Course Outcome:	1. To draw, plot and interpret seismic data and solve structural geology maps.	

SEMESTER IV

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 609
Title of the Course: Academic Research Practices
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To provide a general frame work for enhancing research integrity by focusing on potential threats and good research practices.	
Content:	Introduction - values underlying research integrity, Framework for Good Academic Research Practices, Research Design – Planning, Research problem and Documentation, Literature Review, Conducting Research and Execution. Documentation and Data Storage, Checks for Plagiarism, Falsification, Fabrication, and Misrepresentation, Collaboration, Authorship, Choosing the Right Journal for Publication, Criteria adopted, Institutional Research Programme Management; presentation, training; conflict of interest; conclusion, acknowledgements.	15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments.	
References/Readings:	1.Patwardhan, B., Desai, A., Nag, S. and Bhatnagar, R. (2020).*Guidance document: Good academic Research Practices.* New Delhi: University Grants Commission.	
Course Outcome:	1. This study provides a frame work for good research practices at academic institutions and to understand the value of research in higher education.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 610
Title of the Course: Advanced Research Analysis
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the Course:	Students who have undergone M.Sc. Part I.	
Objective:	To introduce the student to various facets of marine processes, gain some familiarity with different aspects of ocean research, and identify resources for reading, synthesizing, and discussing peer-reviewed journal articles.	
Content:	Presentations by the discipline faculty focusing on the methods and techniques used adopted in research work, data collection and analysis. The students will be briefed and demonstrated the approach to be adopted to develop analytical mindset to identify a problem. Analysis and interpretation of a peer-reviewed journal articles. Students will select and present a peer reviewed paper closely related to the research topic to the discipline faculty and other students. Data collected and discussed during the course will be analyzed in a culminating report.	15 hrs.
Pedagogy:	Presentations in the form of seminar.	
References/ Readings:	1.Text books and advanced research papers and relevant documents related to presentation.	
Course outcome:	1. To develop an analytical mind to select and address a research problem.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 611
Title of the Course: Fundamentals of IPR and patents
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To appraise basic concepts of IPR related to biodiversity.	
Content:	Biodiversity and Intellectual Property Rights (IPR), concepts, need and limitations. Bio-piracy, copyright and neighbouring laws, life patenting and implications, impact of GATT on farmer's rights, indigenous resources, agreements and treaties, traditional knowledge and IPR, biodiversity conservation and IPR, Biodiversity Act.	15 hrs.
Pedagogy:	Lectures/ tutorials/assignments/self-study	
References/ Readings:	1.Saha, C. N. and Bhattacharya, S. (2011). *Intellectual property rights: An overview and implications in pharmaceutical industry*. Journal of Advanced Pharmaceutical Technology Research, 2(2):88-93. doi: 10.4103/2231-4040.82952. 2.Ramakrishna, B. and Anil Kumar, H. S. (2017). Fundamentals of Intellectual Property Rights: For Students, Industrialist and Patent Lawyers Paperback. Notion Press, Chennai.	
Course Outcome:	1. Provides a view of the Marine Biodiversity with emphasis on Intellectual Property Rights, conservation policies and laws.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 612
Title of the Course: Scientific Writing
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To understand scientific paper writing.	
Content:	Scientific writing – understanding the art of research manuscript writing, structure, composition – title, abstract, keywords, introduction, methods and methodology, results and discussion, conclusions, acknowledgement, reference citation in the manuscript text and list of cited references using softwares, plagiarism verification, selection of appropriate and UGC-CARE/SCOPUS listed journals, impact factor, citation index, open access and with subscription.	15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments/ Self-study	
References/Readings:	*1.Booth, W. C., Colomb, G. G. and Williams, J. M. (2009). The Craft of Research. University of Chicago Press.* *2.Canagarajah, A. S. (2002). A Geopolitics of Academic Writing. University of Pittsburgh Press.* 3.Coinam, D. (2004). *Concordancing Yourself: A Personal Exploration of Academic Writing.* Language Awareness, 13, 49-55. *4.Phyllis, C. and Mary, L. (2008). Writing at University: A Guide for Students. UK: McGraw-Hill Education.* 5.Murray, R. and Sarah, M. (2006). *The Handbook of Academic Writing: A Fresh Approach.* Maidenhead: Open University Press. 6.Paltridge, B. (2004). *Academic Writing.* Language Teaching, 37, 87-105.	
Course Outcome:	1. To develop skills in scientific paper writing.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 613
Title of the Course: Capture Fisheries and Overfishing
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the Course:	Students who have undergone M.Sc. Part I.	
Objective:	To provide knowledge on marine fisheries of the World and India with regard to species composition, exploitation and the impact on habitats.	
Content:	World and Indian capture fisheries, Responsible fisheries and sustainable development, Fishing down the marine food webs. Trophic chain and the energy flow across the ecosystem. Overfishing in coastal waters, Global and Indian scenario, food web, trophic level, physical effects, by-catch composition, target and non-target catch, discarded catch, role of associated species, factors affecting catch and production, impacts of climate change on fisheries. Potential fishing grounds. Mitigation measures to reduce adverse impacts of fishing on resources. Integration of fisheries into coastal area management. Ecosystem Approach to Fisheries (EAF) management.	15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments/ Self-study	
References/ Readings:	1.Bal, D.V. and Rao, V. K. (1990). *Marine Fisheries of India.* Tata McGrawHill. 2.Modayil, M. J. and Jayaprakash, A. A. (2003). *Status of Exploited Marine Fishery Resources of India.* CMFRI, Kochi. 3.Christensen, V. and Pauly, D. (1993). *Trophic Models of Aquatic Ecosystems.* ICLARM Conference Proceedings No. 26. ICLARM Manila, Philippines. 4.Christensen, V. and Pauly, D. (1995). *Fish production, catches and the carrying capacity of the world oceans.* Naga, The ICLARM Quarterly 18 (3): 34– 40. 5.Pascoe, S. (2005). *By-catch Management and the Economics of Discarding.* Daya Publ. House. 6.Pauly, D. (1983). *Some Simple Methods for The Assessment of Tropical Fish Stocks.* FAO Fish. Tech. Pap. 234, 52 p. 7.Pauly, D. (1999). *Ecosystem consideration and the limitations of Ecosim models in fisheries management: insights from the Bering Sea.* In: Keller, S. (Ed.) Ecosystem Approaches for Fisheries Management, University of Alaska Sea grant, Fairbanks, pp. 609–618.	
Course Outcome:	1. The students will be apprised of trends in World and Indian fisheries with emphasis on overfishing and its impact.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 614
Title of the Course: Tropical Cyclones
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the Course:	Students who have undergone M.Sc. Part I.	
Objective:	To learn cyclogenesis and characteristics of tropical cyclones.	
Content:	Definition, classification, climatology of tropical cyclone formation, tropical cyclone, warning centers; an overview of symmetric and asymmetric structures of tropical cyclones, including spiral rainbands and polygonal eyewalls, and theirpotential importance to tropical cyclone, temperature and wind structure and intensity change, vertical hot towers. Primary circulation; secondary circulation; frictional inflow boundary layer; dynamic structure, such as vorticity, angular momentum, inertial stability.	15 hrs.
Pedagogy:	Lectures/ Tutorials/ Assignments	
References/ Readings:	1.Bortkovskii, R. S. (1987). *Air Sea exchange of heat and moisture during storms.* Revised English edition by Edward C. Monahan. Springer. 2.Asnani, G. C. (1993). *Tropical Meteorology (Vol. 1 & 2).* Asnani, G. C., Asnani Publ., Pune, India. 3.Houghton, J. T. (1995). *Climate Change*. Cambridge University Press, U.K. 4.Pant, G. B. and Kumar, K. R. (1997). *Climates of South Asia.* John Wiley. 5.Velden, C. et al. (2006). *The Dvorak Tropical Cyclone Intensity Estimation Technique: A Satellite-Based Method that Has Endured for over 30 Years*. Bull. Amer. Meteor. Soc., 87, 1195–1210. 6.Charabi, Y. and Al-Hatrushi, S. (2010). *Indian Ocean Tropical Cyclones and Climate Change*. Springer. 7.Mohanty, U. C., Mohapatra, M., Singh O. P., Bandopadhyay, B. K. and Rathore, L. S. (2014). *Monitoring and Prediction of Tropical Cyclones in the Indian Ocean and Climate Change.* 8.Anthes, R. A. (1982). *Tropical Cyclones: Their Evolution, Structure and Effects.*AmericamMetorological Society. 9.Mohapatra, M., Bandopadhyay, B. K. and Rathore, L. S. (2017). *Tropical Cyclone Activity over the North Indian Ocean.* Springer International Publishing, Cham, Switzerland, with Capital Publishing Company.	
Course outcome:	1. Learn structure of cyclone and its formation.	

Name of the Programme: M. Sc.Marine Sciences
Course Code: MSC 615
Title of the Course: Nitrogen and climate change
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	Understand nitrogen cycling in the marine environment and its role in climate.	
Content:	Nitrogen (N) species in the marine environment; Primary routes for entry of N into the marine environment; Spatial and seasonal distribution of dissolved nitrogen compounds in seawater. Biogeochemical cycling of N; Controlling factors; analytical methods for the study of N compounds; Disruptions caused to marine N cycle due to seawater stratification and upwelling; Impact of agricultural activities, fossil fuel burning and aquaculture; Overview of Greenhouse gases, Nitrous oxide as a driver of climate change, Influence of global warming, deoxygenation and acidification on oceanic N_2O cycling and emissions to the atmosphere, Mitigation strategies for excess N in aquatic systems.	15 hrs.
Pedagogy:	Lectures/ case studies/ tutorials/ videos/ assignments/ self-study	
References/ Readings:	1.Bonaglia, S. (2015). *Control factors of the marine nitrogen cycle : The role of meiofauna, macrofauna, oxygen and aggregates* (PhD dissertation, Department of Geological Sciences, Stockholm University). 2.Capone, D.G., Bronk, D. A., Mulholland, M. R.and Carpenter, E. J. (2008).*Nitrogen in the marine environment*. (Second Edition). Academic Press. 3.Capone, D. G. and Hutchins, D.A. (2013). *Microbial biogeochemistry of coastal upwelling regimes in a changing ocean*. Nature Geoscience, 6, 711-717. 4.Fowler, D., Coyle, M., Skiba, U., Sutton, M. A., Cape, J.N., Reis, S., Sheppard, L.J., Jenkins, A., Grizzetti, B., Galloway, J. N., Vitousek, P., Leach, A., Bouwman, A.F., Butterbach-Bahl, K., Dentener, F., Stevenson, D., Amann, M. and Voss, M. (2013). *The global nitrogen cycle in the twenty-first century. Philosophical* Transactions of the *Royal Society B:* Biological Sciences, 368, 1621. 5.Hutchins, D. A. and Capone, D.G. (2022). *The marine nitrogen cycle: new developments and global change.* Nature Reviews Microbiology.https://doi.org/10.1038/s41579-022-00687-z. McCarthy, M.D. and Bronk, D.A. (2008). ***Analytical methods for the study of nitrogen.*** **In:** D.G. Capone, D.A. Bronk, M.R. Mulholland, E.J. Carpenter (Eds.). *Nitrogen in the Marine Environment* (Second Edition). Academic Press.	
Course Outcome:	1. Understand nitrogen biogeochemistry in marine environment and its role in regulating climate.	

Name of the Programme: M. Sc. Marine Sciences
Course Code: MSC 616
Title of the Course: Air pollution
Number of Credits: 01
Effective from AY: 2022-23

Prerequisites for the course:	Students who have undergone M.Sc. Part I.	
Objective:	To understand the significance of aerosols.	
Content:	Composition of atmosphere, Chemical and photochemical reactions in the atmosphere. Primary Pollutants: Carbon monoxide (CO), Nitrogen oxide (NO_x), Hydrocarbons (HC), Sulphur oxides (SO_2), and Particulates – their sources, sinks, and control methods. Air quality standards. Greenhouse effect/global warming. Effect of man's activities in the atmosphere.	15 hrs.
Pedagogy:	Lectures/Tutorials/ assignments	
References/ Readings:	1.Seinfeld, J. H. (2006). Atmospheric Chemistry and Physics- from air pollution to climate change. John Wiley. 2.Liou, K., (2006). Radiation and cloud processes in the atmosphere-theory, observation, and modeling. Oxford University Press. 3.Kondrateyev, K. Y., Ivlev, L. S., Krapivin, V. F. and Varostos, C. A. (2006). Atmospheric aerosol properties. Springer Praxis Book. 4.Stull, R. B. (1999). An introduction to boundary layer meteorology. Academic Publishers. 5.Fadnavis, S., Mahajan, A. S., Choudhury, A. D. (2020). Atmospheric aerosols and trace gases. In: Assessment of climate change over the Indian Region: A report of the Ministry of Earth Sciences (ir3ew2q1MoES), Government of India. Springer. 93–116. https://doi.org/10.1007/978981-15-4327-2_5. 6.Fadnavis, S., Chavan, P., Joshi, A., Sonbawne, S. M., Acharya, A., Devara, P. C. S., Rap, A., Ploeger, F., and Müller, R. (2022). Tropospheric warming over the northern Indian Ocean caused by South Asian anthropogenic aerosols: possible impact on the upper troposphere and lower stratosphere. Atmospheric Chemistry and Physics. 22, 7179–7191. https://doi.org/10.5194/acp-22-7179-2022, 2022. 7.Yadav, K., Sarma, V. V. S. S., Kumar, M. D. (2020). Spatial and temporal variability in concentration and characteristics of aerosols at Visakhapatnam (east) and Goa (west) coasts of India. Environmental Science and Pollution Research, 27: 532-546. DOI: 10.1007/s11356019-06784-6.	
Course Outcome:	1. Understanding of air pollution and its effect.	