Goa University
P.O. Goa University, Taleigao Plateau, Goa 403 206, India
Syllabus of M. Sc. (Marine Sciences) Programme

The Academic council in its meeting held on 15/11/2018, approved the minutes of the meeting of Board of studies in Marine Sciences held on 26/10/2018.

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, practical): 1 credit (theory) shall be equivalent to 12 clock hours of contact teaching. 12 clock hours are inclusive of lectures/group discussion/seminars/problem solving/tutorials/assessment, 1 credit (practical) shall be equivalent to 24 clock hours of contact teaching, i.e. 12 practical of 2 clock hours duration each. The assessment of the courses shall be fully internal and 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 40:60. Each Internal Semester assessment (ISA) shall be evaluated for 20% of the total marks of the course. Total number of ISA for each Course shall be two irrespective of the number of credits. An additional assessment irrespective of number of credits of course carries, will be provided on the request of students to improve the grade, in which case the assessment with the least score shall not be considered for ISA. However, for 1 credit course, a single ISA shall be conducted and evaluated for 40% of total marks of the course. 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; SEA carrying above 50 marks shall be of three 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 64 credits. Student shall not be allowed to register for less than 10 credits and more than 25 credits in a semester. A student must obtain 48 credits from the parent Department remaining 16 credits may be earned by the student by opting for courses (optional) either from the parent Department or from any other Department of the University.

Dissertation: Dissertation is optional. Topics will be assigned at the end of 2nd semester and the study will begin from starting of 3rd semester. There will be a continuous internal monitoring by the guiding/supervising teacher.

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

Course Structure for M.Sc. Marine Science with effect from June, 2018-19

Semester I

Course code	Course Title	L-T-P hrs/week	Credits	Page no.
MSC 161 (Core)	Physical Oceanography I	3-0-0	3	
MSC 162 (Core)	Marine Chemistry I	3-0-0	3	
MSC 163 (Core)	Marine Biology I	3-0-0	3	
MSC 164 (Core)	Marine Geology I	3-0-0	3	
MSC 165 (Core)	Physical Oceanography Practical I	0-0-2	1	
MSC 166 (Core)	Marine Chemistry Practical I	0-0-2	1	
MSC 167 (Core)	Marine Biology Practical I	0-0-2	1	
MSC 168 (Core)	Marine Geology Practical I	0-0-2	1	

Total No. of Credits 16: Core : 16 ; Optional 0 ;Theory: 12 Practicals: 4

Semester II

Course code	Course Title	L-T-P hrs/week	Credits	Page no.
MSC 261 (Core)	Computational Methods in Oceanography	4-0-0	4	
MSC 262 (Core)	Computational Methods in Oceanography Practical	0-0-4	2	
MSC 263 (Core)	Law of the Sea and Coastal Regulation Zone	2-0-0	2	
MSO 264 (Optional)	Remote sensing and its applications	4-0-0	4	
MSO 265 (Optional)	Remote sensing and its applications Practical	0-0-4	2	
MSO 266 (Optional)	Analytical chemistry of sea water and instrumental techniques Practical	4-0-0	4	
MSO 267 (Optional)	Analytical chemistry of sea water and instrumental techniques Practical	0-0-4	2	
MSO 268 (Optional)	Aquaculture	4-0-0	4	
MSO 269 (Optional)	Aquaculture Practical	0-0-4	2	
MSO 270 (Optional)	Physical Oceanography II	1-0-0	1	
MSO 271 (Optional)	Physical Oceanography practical II	0-0-2	1	
MSO 272 (Optional)	Marine Chemistry II	1-0-0	1	
MSO 273 (Optional)	Marine Chemistry Practical II	0-0-2	1	
MSO 274 (Optional)	Marine Biology II	1-0-0	1	
MSO 275 (Optional)	Marine Biology Practical II	0-0-2	1	
MSO 276 (Optional)	Environmental Impact Assessment	1-0-0	1	
MSO 277 (Optional)	Environmental Impact Assessment Practical	0-0-2	1	
MSO 278 (Optional)	GIS applications in Marine Science Practical I	0-0-2	1	
MSO 279 (Optional)	GIS applications in Marine Science Practical II	0-0-2	1	
MSO 280 (Optional)	Marine chemistry Practical III	0-0-1	1	

MSO 281 (Optional)	**Marine chemistry Practical IV**	**0-0-1**	**1**	

Total No. of Credits 16: Core : 08; Optional 08 ;Theory: 11 Practicals: 5

Semester III

Course code	Course Title	L-T-P hrs/week	Credits	Page no.
Physical Oceanography Specialization				
MSO 361 (Optional)	**Geophysical Fluid Dynamics**	**4-0-0**	**4**	
MSO 362 (Optional)	**Geophysical Fluid Dynamics Practical**	**0-0-4**	**2**	
MSO 363 (Optional)	**Ocean Atmosphere Coupling and Climate**	**4-0-0**	**4**	
MSO 364 (Optional)	**Ocean Atmosphere Coupling and Climate Practical**	**0-0-4**	**2**	
MSO 365(Optional)	**Marine Pollution**	**4-0-0**	**4**	
MSO 366(Optional)	**Marine Pollution Practical**	**0-0-4**	**2**	
MSO 367 (Optional)	**Bioaccumulation and Phytoremediation**	**3-0-0**	**3**	
MSO 368 (Optional)	**Bioaccumulation and PhytoremediationPractical**	**0-0-2**	**1**	
MSO 369 (Optional)	**Aerosol and Climate**	**3-0-0**	**3**	
MSO 370 (Optional)	**Aerosol and Climate Practical**	**0-0-2**	**1**	
MSO 371 (Optional)	**Marine Microbial Ecology I**	**3-0-0**	**3**	
MSO 372 (Optional)	**Marine Microbial Ecology II**	**1-0-0**	**1**	
MSO 373 (Optional)	**Marine Microbial Ecology Practical I**	**0-0-2**	**1**	
MSO 374 (Optional)	**Marine Microbial Ecology Practical II**	**0-0-2**	**1**	
Marine Chemistry Specialization				
MSO 365 (Optional)	**Marine Pollution**	**4-0-0**	**4**	
MSO 366 (Optional)	**Marine Pollution Practical**	**0-0-4**	**2**	
MSO 375 (Optional)	**Marine Geochemistry I**	**2-0-0**	**2**	
MSO 376 (Optional)	**Marine Geochemistry II**	**1-0-0**	**1**	
MSO 377 (Optional)	**Marine Geochemistry III**	**1-0-0**	**1**	
MSO 378 (Optional)	**Marine Geochemistry Practical I**	**0-0-2**	**1**	
MSO 379 (Optional)	**Marine Geochemistry Practical II**	**0-0-2**	**1**	
MSO 363 (Optional)	**Ocean Atmosphere Coupling and Climate**	**4-0-0**	**4**	
MSO 364 (Optional)	**Ocean Atmosphere Coupling and Climate Practical**	**0-0-4**	**2**	
MSO 367 (Optional)	**Bioaccumulation and Phytoremediation**	**3-0-0**	**3**	
MSO 368 (Optional)	**Bioaccumulation and Phytoremediation Practical**	**0-0-2**	**1**	
MSO 369 (Optional)	**Aerosol and Climate**	**3-0-0**	**3**	
MSO 370 (Optional)	**Aerosol and Climate Practical**	**0-0-2**	**1**	
MSO 371 (Optional)	**Marine Microbial Ecology I**	**3-0-0**	**3**	

MSO 372 (Optional)	**Marine Microbial Ecology II**	**1-0-0**	**1**	
MSO 373 (Optional)	**Marine Microbial Ecology Practical I**	**0-0-2**	**1**	
MSO 374 (Optional)	**Marine Microbial Ecology Practical II**	**0-0-2**	**1**	
Marine Biology Specialization				
MSO 380 (Optional)	**Marine Ecology**	**4-0-0**	**4**	
MSO 381 (Optional)	**Marine Ecology Practical**	**0-0-4**	**2**	
MSO 363 (Optional)	**Ocean Atmosphere Coupling and Climate**	**4-0-0**	**4**	
MSO 364 (Optional)	**Ocean Atmosphere Coupling and Climate Practical**	**0-0-4**	**2**	
MSO 365 (Optional)	**Marine Pollution**	**4-0-0**	**4**	
MSO 366 (Optional)	**Marine Pollution Practical**	**0-0-4**	**2**	
MSO 367 (Optional)	**Bioaccumulation and Phytoremediation**	**3-0-0**	**3**	
MSO 368 (Optional)	**Bioaccumulation and Phytoremediation Practical**	**0-0-2**	**1**	
MSO 369 (Optional)	**Aerosol and Climate**	**3-0-0**	**3**	
MSO 370 (Optional)	**Aerosol and Climate practical**	**0-0-2**	**1**	
MSO 371 (Optional)	**Marine Microbial Ecology I**	**3-0-0**	**3**	
MSO 372 (Optional)	**Marine Microbial Ecology II**	**1-0-0**	**1**	
MSO 373 (Optional)	**Marine Microbial Ecology Practical I**	**0-0-2**	**1**	
MSO 374 (Optional)	**Marine Microbial Ecology Practical II**	**0-0-2**	**1**	
Marine Geology Specialization				
MSO 382 (Optional)	**Sedimentology**	**4-0-0**	**4**	
MSO 383 (Optional)	**Sedimentology Practical**	**0-0-2**	**2**	
MSO 375 (Optional)	**Marine Geochemistry I**	**2-0-0**	**2**	
MSO 376 (Optional)	**Marine Geochemistry II**	**1-0-0**	**1**	
MSO 377 (Optional)	**Marine Geochemistry III**	**1-0-0**	**1**	
MSO 378 (Optional)	**Marine Geochemistry Practical I**	**0-0-2**	**1**	
MSO 379 (Optional)	**Marine Geochemistry Practical II**	**0-0-2**	**1**	
MSO 363 (Optional)	**Ocean Atmosphere Coupling and Climate**	**4-0-0**	**4**	
MSO 364 (Optional)	**Ocean Atmosphere Coupling and Climate Practical**	**0-0-4**	**2**	
MSO 367 (Optional)	**Bioaccumulation and Phytoremediation**	**3-0-0**	**3**	
MSO 368 (Optional)	**Bioaccumulation and Phytoremediation Practical**	**0-0-2**	**1**	
MSO 369 (Optional)	**Aerosol and Climate**	**3-0-0**	**3**	
MSO 370 (Optional)	**Aerosol and Climate Practical**	**0-0-2**	**1**	
MSO 371 (Optional)	**Marine Microbial Ecology I**	**3-0-0**	**3**	
MSO 372 (Optional)	**Marine Microbial Ecology II**	**1-0-0**	**1**	
MSO 373 (Optional)	**Marine Microbial Ecology Practical I**	**0-0-2**	**1**	

MSO 374 (Optional)	**Marine Microbial Ecology Practical II**	**0-0-2**	**1**	

Total No. of Credits 16: Core: 0; Optional 16 ; Theory: 11 Practicals: 5

Semester IV

Course code	Course Title	L-T-P hrs/week	Credits	Page no.
Physical Oceanography Specialization				
MSC 461 (Core)	**Estuarine and Coastal Physical Oceanography**	**1-0-0**	**1**	
MSC 462 (Core)	**Estuarine Chemistry**	**1-0-0**	**1**	
MSC 463 (Core)	**Estuarine Biology**	**1-0-0**	**1**	
MSC 464 (Core)	**Estuarine and Coastal Geology**	**1-0-0**	**1**	
MSC 465 (Core)	**Dynamic Oceanography I**	**2-0-0**	**2**	
MSC 466 (Core)	**Dynamic Oceanography II**	**2-0-0**	**2**	
MSD 480 (Optional)	**Dissertation**	**0-0-2**	**8**	
Marine Chemistry Specialization				
MSC 461 (Core)	**Estuarine and Coastal Physical Oceanography**	**1-0-0**	**1**	
MSC 462 (Core)	**Estuarine Chemistry**	**1-0-0**	**1**	
MSC 463 (Core)	**Estuarine Biology**	**1-0-0**	**1**	
MSC 464 (Core)	**Estuarine and Coastal Geology**	**1-0-0**	**1**	
MSC 467(Core)	**Physical and Inorganic Chemistry of seawater**	**4-0-0**	**4**	
MSD 480 (Optional)	**Dissertation**	**0-0-2**	**8**	
Marine Biology Specialization				
MSC 461 (Core)	**Estuarine and Coastal Physical Oceanography**	**1-0-0**	**1**	
MSC 462 (Core)	**Estuarine Chemistry**	**1-0-0**	**1**	
MSC 463 (Core)	**Estuarine Biology**	**1-0-0**	**1**	
MSC 464 (Core)	**Estuarine and Coastal Geology**	**1-0-0**	**1**	
MSC 468(Core)	**Marine Biodiversity Conservation and Practices**	**4-0-0**	**4**	
MSD 480 (Optional)	**Dissertation**	**0-0-2**	**8**	
Marine Geology Specialization				
MSC 461 (Core)	**Estuarine and Coastal Physical Oceanography**	**1-0-0**	**1**	
MSC 462 (Core)	**Estuarine Chemistry**	**1-0-0**	**1**	
MSC 463 (Core)	**Estuarine Biology**	**1-0-0**	**1**	
MSC 464 (Core)	**Estuarine and Coastal Geology**	**1-0-0**	**1**	
MSC 469(Core)	**Tectonics, Geophysics and Structural Geology**	**4-0-0**	**4**	
MSD 480 (Optional)	**Dissertation**	**0-0-2**	**8**	

Total No. of Credits 16: Core : 08; Optional (Dissertation) 08 ;Theory: 08 Practicals: 0

SEMESTER I

Programme: M. Sc. (Marine Sciences)
Course Code:MSC 161 **Title of the Course: Physical Oceanography I**
Number of Credits: 03
Effective from AY: June, 2018-19

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent.	
Objective:	Students with any branch in science at their graduation level are eligible to get admission to PG in Marine Science. Ocean, being a dynamic ecosystem, to know the biology, geology and chemistry of the Ocean, it is imperative to know different physical process responsible to drive the system.	
Content:	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 seawater-Salinity – Temperature-Density-Distribution of temperature - salinity and density in space and time- Oceanic mixed layer and thermo-cline – Measurement of temperature and salinity - Sound in the sea. Propagation of sound in the sea-Light in the sea – The Oceanic heat budget. The earth in space – Atmospheric wind systems – Composition of atmosphere - Vertical extent of atmosphere -Planetary boundary layer – Measurement of wind – Calculations of wind stress - Coriolis force- General circulation of atmosphere-Atmospheric temperature -Temperature system and scales - Atmospheric humidity - Vapour pressure - Circulation – Wind- driven and thermo-haline circulations – Importance of deep circulation – Theory for deep circulation. Equatorial processes - El Nino – El Nino tele-connection - Southern Oscillation and Indian Ocean Dipole (IOD) - Indian Ocean Circulation. T.S.V. diagram- T.S. diagram - Oceanic fronts -Upwelling - Water masses in the ocean - Bottom water - Deep water - Antarctic intermediate water - Central water - Lagrangian and Eulerian methods for measuring currents.	12 hours 12 hours 12 hours
Pedagogy:	The course is being taught adopting conventional method of class room teaching using chalk and board. However, after each module an integral picture is drawn to them through power point presentation. In addition students are given seminar topics related to the course.	
References/ Readings	1. The Ocean: Their Physics, Chemistry and Biology, 1962 - Sverdrup, H.U., Johnson, M.W. and Flemming, R.H., Asia Publ. House, New Delhi. 2. Descriptive Physical Oceanography: An Introduction, 1989 - Pickard, G.B. and Emery, W.J., Pergamon press, U.K. 3. Principles of physical oceanography, 1966 - Pierson, W.J. and Newmann, G.S., Prentice Hall, Inc., New Jersey, U.S.A. 4. Meteorology Today: An Introduction to weather, climatic and the environment (2nd edn), 1985 - Ahrens, St. Paul, West Publ. House, U.K. 5. Meteorology: Forecasting the weather, 1973 - Wachter, H., Collins Publ., U.K. 6. The Atmosphere and Ocean: A physical Introduction, 1986 - Wells, N., Taylor and Francis Ltd., U.K. 7. General Climatology, 1960 - Critchfeild, H.J., Prentice Hall Inc., New Jersey, U.S.A. 8. Introduction to Micrometeorology, 2nd edition, 2001 - S. Pal Arya, Vol 79 in International geophysics Series, Academic press.	
Learning Outcomes	Getting a larger picture of a coupled ocean – atmosphere and the different process involved in controlling the ecosystem.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 162 **Title of the Course: Marine Chemistry I**
Number of Credits: 03
Effective from AY: June, 2018-19

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 develops concepts about the chemistry of the marine environment that concerns the study of the properties and interactions of the substances present in the marine environment.

Content:	Symbols and units used in chemical oceanography – Major and minor elements in seawater – Geochemical balance of the oceans, residence times, chemical speciation. 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, Chlorinity and salinity: definition and significance, practical salinity scale, Radioactive nuclides in the sea. Dissolved gases (other than CO_2) in seawater – Basic concepts : 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, 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.	12 hours 12 hours 12 hours
Pedagogy:	Lectures/ tutorials/ assignments/ self-study	
References/ Readings	1. Introduction to Marine Chemistry, 1971 – Riley, J.P. and Chester, R., Academic Press. 2. Chemical Oceanography (Vol.1, 2, 3 & 8), 1975 – Riley, J.P. &Skirrow, G., Academic Press. 3. Marine Chemistry, 1969 – Horne, R.A., Wiley-Interscience 4. Seawater: Its composition, properties &behaviour, 1989, 1995, 2004 – The Open University. 5. Marine Chemistry (Vol.2), 1970 – Martin, D.F., Marcel Dekker, NY. 6. Tracers in the Sea, 1982 – Broecker and Peng., Lamont-Doherty Geological Observatory, NY. 7. Marine Geochemistry, 1990, 2000 – Chester, R., Blackwell Science. 8. Chemical Oceanography, 1992 – Millero, F. J. and Sohn, M.L., CRC Press. 9. Dynamic processes in the chemistry of the upper ocean, 1986 - Burton et al., Plenum Press. 10. The chemistry of the Atmosphere and Oceans, 1978 – Holland, H.D., Wiley. 11. An Introduction to Environmental Chemistry, 1996 – Andrews et al., Blackwell science. 12. Environmental Chemistry, 1994 - De, A.K., Wiley – Eastern Ltd. 13. Geosphere – Biosphere Interactions and Climate, 2001 – L.O.Bengtsson and C.U.Hammer., Cambridge University Press. 14. Oceanography of the Indian Ocean, 1992 – B. N. Dessai (Ed.), AA Balkema. 15. Chemical Oceanography of the Indian Ocean, North of Equator. 1984, Sengupta and Naqvi, Deep Sea Res. 31A, 671-706. 16. Chemical Oceanography, 1996, 2006 – F. J. Millero, CRC Press. 17. The Sea Surface and Global Change, 1997, 2005 – P.S. Liss and R. Duce., Cambridge University Press. 18. Ocean Biogeochemistry: The role of the ocean carbon cycle in Global change, 2003 – M.J.R. Fasham, Springer. 19. An Introduction to Marine Biogeochemistry, 2nd edition, 2009 – S.B.Libes, Wiley. 20. Marine Chemistry and Geochemistry, 2010 – K. K. Turekian, Academic Press. 21. An Introduction to the Chemistry of the Sea, 2nd edition, 2013 – M.E.Q. Pilson, Cambridge University Press.	
Learning Outcomes	1. Provide a comprehensive understanding of the properties and interactions of the substances present in the marine environment. 2. Explain the key processes operating in the marine environment. 3. Explain the importance of dissolved O_2, the marine carbon cycling and the CO_2 problem. 4. Explain the biogeochemical cycling of the trace metals from the perspective of the global biogeochemical cycling of elements.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 163 **Title of the Course: Marine Biology I**
Number of Credits: 03
Effective from AY: June, 2018-19

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 addresses the 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:	Introduction to marine biology, history, classification, theories, hypothesis testing; life and non life, Origin and evolution of life, life processes, abio-genesis, theories of natural selection, models and hypothesis of organic evolution, primordial soup hypothesis, organic molecules, chemical evolution, iron sulfide and black smoker's theory, RNA world hypothesis, theory of evolution and panspermia. Biotic structure, Invertebrate larvae and their biology, larval types and strategies, theories of bi-phased life history, Marine and coastal environment, biological zonation, inter-tidal ecosystem, rocky, sandy and protected sand flats, zonation pattern, physical and biological factors and processes affecting biotic communities and their adaptations. Sea as a biological environment, physiological changes, regulators and conformers, scope for growth, temperature and metabolic rates, comparison among marine and terrestrial environment, Organic matter production, Marine primary productivity, photo-autotrophic production, mechanism, light and dark reaction, intermediate products, role of pigments, methods of assessment, factor and processes affecting primary productivity, transformation of organic matter, vertical profile of primary productivity and SCM, turbulence and MLD.	12 hours 12 hours 12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/ Readings	1. Marine Biology. 8th Edition – 2009 Castro, P. and Huber, M. McGraw Hill Education. 461 pp. 2. Introduction to Marine Biology. 4th Edition. – 2012, Krleskint, G., Turner, R., Small, J., Cengage Learning. 576 pp 3. Biological oceanography 1999 – Lalli, C.M., Elsevier Ltd. 4. Oceanography: The past, 1980 – Sears, M and Merimann D. (Eds)., Springer- Verlag 5. Elements of Marine ecology (4th edn) 1982 – Tait, R.V. and Dipper, F. Butterworth - Heinemann 6. An introduction to Marine Sciences, 1988 – Meadows, P.S. & Campbell, J.J., Springer Science & Business Media 7. Textbook of Marine Ecology, 1980 – Nair, N.B. &Thampy, D.M., Macmillan, 352 pp. 8. Marine Biology, 1984, Thurman, H.V. and Webber, H.H., Harper Collins Publishers 9. Methods in Marine Zooplankton Ecology, 1984 Omori, W. and Ikeda, T. Wiley 10. Methods for the study of Marine Benthos, 1984 – Holme, N.A. &Melntyre, A.D. Blackwell Scientific Publications 11. The Ecology of Rocky Coasts, 1964 – Lewis, J.R. English Universities Press 12. The shore environment, 1980 – Irvine, J.H., Price, D.E.C. and Farnham, W.F. Systematics Association 13. Life between tidemark on rocky shores, 1972 – Stephenson, T.A. & Stephenson, A. W. H. Freeman 14. The invertebrates (3rdthEdn.), 1986 – Barnes, R.S. K. Blackwell Science 15. Zooplankton Methodology Manual, 2000 - Harris, R., Wiebe, P., Lenz, J., Skjoldal, H.R., Huntley, M. (Eds), ICES Academic Press, San Diego, pp. 68	
Learning Outcomes	Provides fundamental knowledge related to marine life and processes and also the strategies adopted by these groups for survival in marine environment.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 164Title of the Course: Marine Geology I
Number of Credits: 03
Effective from AY: June, 2018-19

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 introduces concepts of Marine Geology andhelps 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:	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. 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. 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.	12 hours 12 hours 12 hours
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings	1. Introductory oceanography (5th ed), 1988 Thurman, H.V., Columbus Mercill Publ. Co, Ohio. 2. Oceanography (5th ed), 1990 Grant Gross, M., Englewood Cliffs, N.J. Prentice Hall. 3. Coastal and estuarine sediment dynamics, 1986 Dyer, K. R., John Wiley & Sons, Wiley, Chichester. 4. Earth resources, 1969 Skinner, B. J., Englewood Cliffs, N.J., Prentice Hall. 5. Marine Geology and Oceanography of the Arabian Sea and coastal Pakistan, 1984 Haq. B. U. and Milliman, J. D., Van Norstrand Reinhold Co. 6. Beach processes and sedimentation, 1976 Komar, P. D., Englewood Cliffs, NJ Prentice Hall. 7. Beaches and Coasts (2nd ed), 1972 King, C. A. M., Edward Arnold, London. 8. Introduction to marine micropaleontology, 1978 Haq, B.U. and Boersma, A. (Eds.), Elsevier Publ. 9. Marine minerals: advances in research and resource assessment, 1987 Teleki, P.G. et al., D. ReidelDordrechart. 10. The micropaleontology of oceans, 1971 Funnell, B. M. and Reidel, W. R., Cambridge Univ. Press., U.K. 11. Marine geology and oceanography of the Arabian Sea and coastal Pakistan, 1984 Haq. B.U. and Milliman, J. D., Van Norstrand Reinhold Co. 12. Marine Geology, 1982 James P. Kennet., Prentice Hall INC Englewood, Cliffs, N. J. 07632.	
Learning Outcomes	1. Understanding earth processes, evolution and mineral resources associated with ocean basins. 2. Ability to reconstruct paleoclimate and paleomonsoon	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 165 **Title of the Course: Physical Oceanography Practical I**
Number of Credits: 01
Effective from AY: June, 2018-19

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent.	
Objective:	Develop skills of preparing graphs and estimate ocean/atmosphere properties that enable study of ocean/atmospheric phenomena.	
Content:	1. Analysis of vertical profiles of temperature, salinity and density to understand the physical processes in different regions at low, mid and high latitude of the world ocean (6hrs; Ref 1) 2. Analysis of vertical profiles of a) temperature, b)salinity and c) density in upwelling and non-upwelling regions of the world ocean (3hrs; Ref 1) 3. Generating vertical section of temperature to study the physical processes along a transect (6hrs; Ref 1, 2) 4. Generating vertical section of salinity to study the physical processes along a transect (6hrs; Ref 1, 2) 5. Generating vertical section of density to study the physical processes along a transect (6hrs; Ref 1, 2)	24 hours

	6. Estimation and analysis of heat content in different parts of World Ocean (3hrs; Ref 3, 4)	
Pedagogy:	Tutorials/assignments/practical/fieldstudy	
References/ Readings	1. Seawater: Its Composition, Properties and Behaviour, 1995 - Second Edition, Open University Press, 2. Ocean Circulation, 2001 - Second Edition, Open University Press, Walton Hall, Milton Keynes, MK76AA, UK 3. Algorithms for computation of fundamental properties of seawater, 1983. UNESCO TECHNICAL PAPERS IN MARINE SCIENCE, Endorsed by UNESCO/SCOR/ICES/IAPSO/ Joint Panel on Oceanographic Tables and Standards and SCOR Working Group 51, Unesco, Place de Fontenoy, 75700, Paris, France 4. Principles of physical oceanography, 1996 – Pierson, W.J. and Newmann, G.S., Prentice Hall Inc., New Jersey, U.S.A.. 5. Introduction to Dynamic Oceanography, 1983 - Pond, S. and Pickard, G.H., PergamonPress, U.K. 6. Tropical Pacific near-surface currents estimated from altimeter, wind, and drifter data. 1999 - Gary S. E. Lagerloef, Gary T. Mitchum, Roger B. Lukas, Pearn P. Niiler., Journal of Geophysical Research, Volume 104, Issue C10, pages 23313–23326. 7. Meteorology Today: An introduction to weather, climate and the environment (2^{nd} edition), 1985 - Ahrens, St. Paul, West Publ. House. 8. Meteorology-Understanding the atmosphere, 2012 - Steven A A	
Learning Outcomes	Explain processes responsible for behaviour of conservative properties of ocean. Understand the importance of sound in sea and know its implications for underwater communication. Know ocean processes along meridional section.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 166 Title of the Course: Marine Chemistry Practical I
Number of Credits: 01
Effective from AY: June 2018-19

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 Seawater.	
Content:	1. Introduction to good laboratory practices in Chemical Lab and introduction to sampling, sub-sampling, storage and analysis of dissolved trace constituents of seawater (6 hrs; Ref 1) 2. Estimation of salinity of seawater by the Mohr- Knudsen chlorinity titration method (6 hrs; Ref 1) 3. Determination of dissolved O_2 of seawater by Winkler's iodometric titration method (6 hrs; Ref 1) 4. Determination of pH of seawater by potentiometric method using pH meter and determination of total alkalinity of seawater by potentiometric titration using pH meter (6 hrs; Ref 1) 5. Spectrophotometry: Verification of Beer's law (6 hrs; Ref 2)	24 hours
Pedagogy:	Laboratory experiments/ field studies	
References/ Readings	1. Methods of Seawater Analysis, 1983, 1999 – Grasshoff, K., Ehrhardt, M. and Kremling, K.; VerlagChemie, Weinheim. 2. Instrumental Methods of Chemical Analysis, 1981 – Ewing, G. W.; McGraw-Hill, New York. 3. A Manual of Chemical and Biological Methods for Seawater Analysis, 1984 – Parsons, T. R., Maita, Y. and Lalli, C. M.; Pergamon Press, Oxford.	
Learning Outcomes	1. Develop analytical skills to determine the concentrations of various chemical parameters, such as salinity, dissolved O_2, pH and alkalinityin seawater/aqueous systems and to use spectrophotometer for the analysis of colored solutions. 2. Apply techniques to seawater/natural waters to study the biogeochemistry of the marine environment/aquatic systems.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 167 **Title of the Course: Marine Biology Practical I**
Number of Credits: 01
Effective from AY: June, 2018-19

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent.	
Objecive:	This course provides information on the sampling devices used for collection of marine organisms from the environment and thereafter identification of biological samples of some of the major groups.	
Content:	1.Introduction to standard sampling devices / instruments employed for collection and analysis of biological parameters in water and sediments used in oceanographic studies (2 hrs; Ref 2) 2.Design and execution of field / sampling surveys for collection and analysis of biological communities (water and sediment), their preservation and storage techniques using standard methods (2 hrs; Ref 3) 3.Identification of marine phytoplankton, their life cycle and role in food chain (2 hrs; Ref 1) 4.Identification of marine zooplankton, their life cycle and role in food chain (2 hrs; Ref 10,11) 5.Identification of mangroves, their life cycle and few biological characteristics (2 hrs; Ref 5)	24 hours
Pedagogy:	Identification of sampling devices, marine flora and fauna	
References/ Readings	1. Phytoplankton Identification Catalogue - Saldanha Bay, South Africa, April 2001, 2013 - Botes, L. (2003), GloBallast Monograph Series No. 7. IMO London. 2. Drawing Techniques for Publication, 2013 - Bowestead D. &EcclesT. M. 3. Museum of Natural History, Oxford University, 23 pp. 4. Available at: http://www.oum.ox.ac.uk/collect/Drawing%20Techniques.pdf 5. Monograph of Shallow-Water Indo-West Pacific Echinoderms, 1971 - Clark A. M. & Rowe F. E. W, Trustees of the British Museum of Natural History, London, 238 pp.	
Learning Outcomes	Develop ability to identify the biological specimens at species level.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 168Title of the Course: Marine Geology Practical I
Number of Credits: 01
Effective from AY: June, 2018-19

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 introduces to experiments tomeasure parameters to understand near-shore and beach dynamics; bathymetry and heavy minerals.	
Content:	1. Field survey (Beach) - locating a station using compass and GPS; Beach profile measurement and sediment sample collection from different parts of the beach (4 hrs; Ref 2) 2. Plotting station locations on the base map and beach profile; volume computation from the given data (2hrs; Ref 2) 3. Conning and quartering, pre-treatment of sediment sample to remove calcium carbonate, organic matter and ferruginous material (2hrs; Ref 1, 6) 4. Grain size analysis (sand) using Ro-tap sieve shaker – batch I (8 hrs; Ref 1, 6) 5. Computation of weight and cumulative percentages, plotting frequency and probability graphs, computation of modes of transport and grain size parameters and interpretation (4 hrs; Ref 1, 6) 6. Heavy mineral separation from different fractions of sand and interpretation (4 hrs; Ref 1, 9) 7. Plot bathymetry lines and interpret geomorphology (4 hrs; Ref 4)	24 hours
Pedagogy:	Field surveys and sampling / Laboratory experiments / Computations / Plotting and Interpretations	

References/ Readings	1. Exercises in sedimentology, 1982 Freidman, G. M. and Johnson K. G., John wiley and sons. 2. Beach processes and sedimentation, 1976 Komar, P. D., Prentice Hall 3. Flume studies on the transport of sediments in estuarine shoaling processes-A report, 1962 Hydraulic 4. Practical manual of sedimentary petrology, 1987 Babu, S. K. and Sinha, D. K., CBS, Publishers and Distributors, Delhi. 5. The mineral sources of the sea, 1965 Mcro, J. L., Elsevier, Amsterdam.	
Learning Outcomes	1. Conducting field survey and sampling 2. Conducting laboratory experiments 3. Ability to interpret data sets to understand processes.	

SEMESTER II

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 261 **Title of the Course: Computational Methods in Oceanography**
Number of Credits: 04
Effective from AY: June, 2018-19

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent.	
Objective:	To impart mathematical, statistical and programming skills that are useful in oceanography	
Content:	Programming FORTRAN (90/95): constants, variables, arithmetic operations, arithmetic expressions – assignment statements – input – output statement - library functions – Hierarchy of operation – mixmode operations- relational operators, precedence of operators. IF-THEN - ELSE statement – ELSEIF structures – NESTED IF blocks – DO LOOP – NESTED DO LOOP – Intrinsic DO LOOP.	12 hours
	Applications of basic Mathematics to oceanography: Indices, Logarithms, linear and parabolic functions – Permutation and combinations – Arithmetic and geometric progression – Differentiation, application of differentiation – Velocity, acceleration, related rates. Application of integration to growth and decay problems - Matrics: addition, subtraction, multiplication, inverse by adjoint method.	12 hours
	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 quatilr deviation, mean deviation and standard deviation – skewness, kurtosis – linear correlation, Karl - Pearson's coefficient of correlation, concurrent deviation method, method of least squares (regression) – regression equation.	12 hours
	Introductory probability- Normal and binomial distribution – Inferential statistics: standard error – significance level – hypothesis testing: students t-test: test of significance for attributes, large samples and small samples, Z test, Ψ^2 (chi square) test, F test, Analysis of Variance.	12 hours
Pedagogy:	Lectures/Tutorials/ assignments	
References/ Readings	1. A biologist's basic mathematics, 1983 – Causton, D.R., Edward Arnold, London, Edward Arnold Publishers Ltd. 2. Statistical Methods in Atmospheric Sciences. 2nd edition., 2011 - Daniel S. Wilks, Academic Press 3. Introduction to mathematics for life scientists, 1971 – Batchelet, E., Springer 4. Mathematics for biological sciences, 1980 – Newby J.C., Oxford University Press, U.K. 5. College algebra, 1966 - Bardell, R.H. and Spitzbart, A., Addision-Wesley, Massachusetts, U.S.A. 6. Introduction to algebra, 1966 – Perlis S., Blaisdell Publ. Co., London. 7. Differential equations, 1985 - Wylic, C.R., McGraw Hill Publ., Singapore. 8. Statistics: Theory methods and applications, 1988 – Samchetr, D.C. and Kapoor, V.K., Sultan Chand and Sons, New Delhi. 9. Biometry, 1981 – Sokal, R.R. and Rohlf, F.J. Freeman & Co. San Fransisco.	

	10. Statistical methods, 1967 – Snedecore, G.W. and Cochran, W.G., Allied Pacific Pvt. Ltd., Mumbai. 11. Multivariate statistical methods, 1990 – Morrison, D.F., Mc.Graw, Hill Publ., Singapore. 12. Fundamental computer concepts, 1986 - Davis, W.S. Mc.Graw Hill Publ., Singapore. 13. Theory and problems of data processing, 1982 – Lipschutz, M.M. and Lipschutz, S., McGraw Hill Book Co., Singapore. 14. Fortran 77 and numerical methods, 1994 Xavier, C., Wiley-Eastern Ltd., New Age International Ltd., New Delhi. 15. Computer Programming in FORTRAN 90/95, 1997. V. Rajaraman, Prentice Hall of India, New Delhi. 16. FORTRAN 90/95 for Scientists & Engineers, 1998 - S.J. Chapman, Mc-Graw Hill.	
Learning Outcomes	Apply techniques of mathematics, statistics in oceanography/meteorology. Acquire computational and programming knowledge to deal with large data sets and generate programs. Plot global ocean/atmosphere data.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 262 **Title of the Course: Computational Methods in Oceanography Practical**
Number of Credits: 02
Effective from AY: June, 2018-19

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent.	
Objective:	To use mathematical /statistical knowledge to estimate ocean/atmospheric parameters and to learn to make computer programs for application in oceanography.	
Content:	**Module - I** 1. Programs illustrating use of Numeric constants & variables, Arithmetic operators & expressions, simple input and output statements, hierarchy of operations. (6hrs; Ref 1,2.3,4) 2. Programs illustrating use of logical expressions, integer, real & mix mode operations & library functions (6hrs; Ref 1, 2,3, 4) 3. Programs illustrating use of IF-ENDIF, IF-ELSE-ENDIF and IF-ELSEIF-ELSE-ENDIF (4hrs; Ref 1,2,3,4) 4. Programs illustrating use of DO loops, nested DO loops (4hrs; Ref 1, 2, 3, 4) 5. Programs illustrating use of one and two dimensional arrays (6hrs; Ref 1, 2, 3, 4) 6. Programs illustrating use of different types of FORMATS (4 hrs; Ref 1, 2, 3, 4) **Module -II** 1. Programs illustrating subroutines and reading/writing data from files - hard disk. (6hrs; Ref 1, 2, 3, 4) 2. Programs for computation of statistical parameters for analysis of oceanographic data. (6hrs; Ref 1 2, 3, 4, 5) 3. Writing programs for sample data extraction and validating (6hrs; Ref 1, 2, 3, 4) 4. Use of statistical software for estimation of statistics/parameter of sample/population (2hrs; Ref 5) 5. Writing programs for data extraction, validating & generating horizontal sections of oceanographic property using software with different gridding method to ascertain the most suitable gridding method. (6hrs; Ref 1, 2, 3, 4 & Surfer software manual) 6. Writing programs for data extraction, validating & generating contour map for analysis of vertical & surface properties (4hrs; Ref 1, 2, 3, 4 & Surfer software manual).	24 hours 24 hours
Pedagogy:	Tutorials/ assignments/practical	
References/ Readings	1. Computer Programming in FORTRAN 90/95, 1997. V. Rajaraman, Prentice Hall of India, New Delhi. 2. Fundamental algorithms, 1985 – Knuth, D.E., Narosa Publ. House, New Delhi. 3. Theory and practice of programming, with FORTRAN, 1986 – Lipschutz, S & Poe, A., McGraw Hill Book Co., Singapore. 4. FORTRAN 90/95 for Scientists & Engineers, 1998 - S.J. Chapman, Mc-Graw Hill. 5. Statistical Methods, 2009 - S C Gupta,Sixth edition, Himalaya publishing House	
Learning Outcomes	Make computer programs involving mathematics, statistics methods for applications in oceanography/meteorology. Acquire computational and programming knowledge to deal with	

	large data sets and generate programs. Plot global ocean /atmosphere data for specific spatial and temporal ranges.	

Programme: M.Sc. (Marine Sciences)
Course Code:MSC 263 **Title of the Course: Law of the Sea and Coastal Regulation Zone**
Number of Credits: 02
Effective from AY: June2018-19

Prerequisites for the course	Students who have undergone courses of semester I of Marine Sciences.	
Objective	This course introduces the law of the Sea and the concept of coastal regulation zone.	
Content	Law of the Sea – Territorial Sea – Contiguous zone – Straits used for international navigation – Archipelagic states – Exclusive economic zone – Continental shelf – High seas – Regime of islands – enclosed or semi-enclosed seas – Right of access of land-locked states – Protection and preservation of marine environment – Scientific and technical assistant – international rules and national legislation to prevent, reduce and control pollution of the marine environment. Coastal Regulation Zone – Demarcation – Prohibited activities – Regulation of permissible activities – Procedure for monitoring and enforcement – Classification of Coastal Regulation Zone – Category I (CRZ-I) – Category II (CRZ-II) – Category III (CRZ-III) – Category IV (CRZ-IV) – Norms for regulation of activities – CRZ-I – CRZ-II – CRZ-III – CRZ-IV – Guidelines for development in the designated areas of CRZ-III – Permitted petroleum products for storage in CRZ.	12 hours 12 hours
Pedagogy	Lectures / Assignments / Seminars / Discussion	
References / Readings	1. United Nations Convention on the Law of the Sea 1982 A Commentary, 2011 volume 7, Nordquist M. N., Martinus Nijhoff Publishers. 2. United Nations Convention on the Law of the Sea, 2009, United Nations, Nova Science Publishers, Inc., New York. 3. Coastal Regulation Zone 2011 and Island Protection Zone 2011 notifications issued 6.1.2011, Ministry of Environment and Forests. 4. Coastal Regulation Zone notification 1991 under E(P)A, 1986 – 19.2.91 5. Coastal Regulation Zone and Island Protection Zone notifications 2011, ICZM project, Ministry of Environment, Forests and Climate change, July 11, 2016.	
Learning Outcomes	1. Understanding of the laws applicable for navigation in sea. 2. Knowledge of international and national legislation to control marine pollution. 3. Understanding coastal regulation zone to prevent the deterioration of coast.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 264Title of the Course: Remote sensing and its applications
Number of Credits: 04
Effective from AY: June, 2018-19

Prerequisites for the course:	Students undergoing course in any branch of Marine Sciences.
Objective:	All the coastal process is transient in nature. They are of either diurnal/weekly time scale. To deal with such variability the requirement is a method that would provide a synoptic coverage of the coastal and offshore regions. This is possible only by means of Remote sensing. Hence this emerging technology has been introduced as a course.

Content:	Principles of Electromagnetic radiation– Energy matter interactions –- Rayleigh scattering – Mie scattering – Non selective scattering - Radiative transfer in the atmosphere – Stfan's and Wien's displacement laws –Zenith and azimuth angles. 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 - spectral response of water as a function of organic and inorganic constituents - Analysis of suspended minerals, chlorophyll *a* and dissolved organic matter through OCM/MODIS data. 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 – MSS, GOES, AVHRR, CZCS, SeaWiFS, IKONOS, MODIS, OCM I and OCM - II, LISS -1, LISS-II, WIFS and PAN – Fundamentals of digital image processing – Image rectification – Image enhancement – linear stretching – supervised and unsupervised classification - Introduction to Geographic Information system.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	Being a new and an emerging field, it is necessary to have class room contact hours. Hence, it is a class room taught course. In addition, to get acquaint with the course,seminar topics on the applications of remote sensing are given to the students at the beginning.	
References/ Readings	1. Physical principles of remote sensing, 1990 – Rees, W.G., Cambridge Univ. Press, U.K. 2. Remote sensing optics and optical systems, 1980 – Slater, P.N., Addision Wesley Publ. Co. 3. Remote sensing and image interpretation (2^{nd}edn), 1987 – Lillesand, T.M. and Kiefer, R.W., John Wiley and sons. 4. Remote sensing: Principles and interpretations (2^{nd}edn), 1987 – Floyd and F. Sabnis Jr. W.H. Freeman and Co., New York. 5. Theory and application of optical remote sensing, 1989 – Asrar G., John Wiley & Sons. 6. Introduction to satellite oceanography, 1985 – Maul, G.A., Martinus Nijhoff Publ. 7. Advanced remote sensing from theory to applications (vol.1, 2 & 3), 1981 – Chlamys, F.T., Addision wisley Publ. Co. Inc., Canada. 8. Oceanography from space, 1987- Gover, J.A.R., Plenum Press, New York. 9. Remote sensing of atmospheres and oceans, 1980 - Deepak A., Academic press. 10. Satellite oceanography, 1985 - Robinson, I.S., John Wiley & Sons	
Learning Outcomes	Since the country is in advanced stage in the field of space Technology, the students opting for this course will be trained Manpower to carry forward Nation's need for human resources in the field of Remote sensing.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 265 **Title of the Course: Remote Sensing and its applications Practical**
Number of Credits: 02
Effective from AY: June, 2018-19

Prerequisites for the course:	Students undergoing course in any branch of Marine Sciences.
Objective:	This course is the practical component of the theory students learn. This involves satellite data processing for various applications of Ocean/earth/ atmosphere. In this course, students will be exposed to different satellite data, various corrections to be applied and finally image processing for a finished geophysical product.

Content:	**Module - I** 1. Field survey and laboratory analysis to generate apparent optical properties from case II waters using in-water radiometer, and profiles of salinity and temperature using conductivity, temperature and Depth (CTD) sensor, (16 hrs; Ref 1) 2. Generation of Inherent Optical properties (IOP) of optically active substances (OAS), namely absorption of chlorophyll-*a* (Chl-*a*), Chromophoric Dissolved Organic Matter (CDOM) and Total Suspended Inorganic Matter (TSM) from water samples collected during the field survey of case II waters (10 hrs; Ref 1) 3. Simulation of remote sensing reflectance and water leaving radiance from case II waters (4 hrs; Ref 2) **Module – II** 1. Simulation of remote sensing reflectance for each optically active substance and delineation of range of wavelengths susceptible to each OAS and development of empirical algorithms (10 hrs; Ref 3) 2. Generation of aerosol optical depth using sun-photometer and analysis of aerosol optical depth to estimate atmospheric turbidity parameter and Angstrom exponent (8 hrs; Ref 4,5,8) 3. Satellite data processing to map chlorophyll *a*, using ERDAS IMAGINE SeaDAS (12 hrs; Ref 6, 7 and 8)	24 hours 24 hours
Pedagogy:	This course is done through various programming to estimate Parameters followed by usage of different image processing packages. One such package student's use is SeaDAS software.	
References/ Readings	1. Regional validation of MERIS CHLOROPHYLL products in North coastal waters (REVAMP) Protocol, based on NASA and colors protocols, 2002 - Tilstone, G.H, Moore, G.F, Sorensen. K, Doerffer. R, Rottgers, K.G, Ruddick. R, Psterkamp, P.V and Jorgensen, ENVISAT – 1 2. Physical principles of remote sensing, 1990 – Rees, W.G., Cambridge Univ. press, U.K. 25 3. Remote sensing: Principles and interpretations (2^{nd} edn), 1987 – Floyd and F. Sabnis Jr, W.H. Freeman & Co., New York. 4. Theory and applications of optical remote sensing, 1989 – Asrar, G., John Wiley & Sons. 5. Introduction to satellite oceanography, 1985 – Maul, G.A., Martinus Nijhoff Publ. 6. Advanced remote sensing from theory to applications (Vol.1, 2 & 3), 1981, Chlamys, F.T., Addison – Wesley Publ. Co. Inc., Canada. 7. Oceanography from space, 1987 – Grover, J.A.R., Plenum Press, New York. 8. Remote sensing of atmospheres and oceans, 1980 – Deepak, A., Academic Press. 9. SBE plus CTD, User's manual www.seabird.com/pdf_documents/manuals/9_plus_017.pdf 10. Regional Oceanography, an Introduction, 2nd edition, 2003 - Tomczak, Mattias and Stuart Godfrey J, , Daya Publishing house, Delhi.	
Learning Outcomes	Students will be thoroughly trained in different process of satellite Data so as to generate various geophysical products.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 266Title of the Course: Analytical Chemistry of Sea water and
Number of Credits: 04 **Instrumental Techniques**
Effective from AY: June, 2018-19

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent.
Objective:	1. The course is aimed at understanding the collection sea water, sediment and biological samples by using different field equipments. 2. To adopt suitable techniques for preservation water, sediment and biological samples for their chemical analyses. 3. The course work is so designed to understand the errors generally occur in the analyses of samples by different techniques. 4. To study different techniques used for extraction of various inorganic chemicals (fresh water, salt, bromine, calcium, magnesium and potassium) and organic chemicals (Agar, Carrageenan and Alginic acid) and 5. To study instruments used (Spectrophotometer, spectrofluorimeter, and flame photometer, AAS, ICP, GC and HPLC) for analyses of different chemical constituents in sea water.

Content:	Sampling – Collection and preservation of water, sediment and biological samples. 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. Fresh water recovery by various methods of desalination, Low temperature thermal desalination, Distillation, solar evaporation, Membrane process, scale formation and its prevention. Chemical recovery process- Chemistry of salt manufacture, Different grades of salt, washing of sea salt, salt for industries, up-gradation of sea salt, solar evaporation, forced evaporation of brine, Grainer process, Alberger process, Open pan evaporation and vacuum pan evaporation methods. Recovery of bromine from salt bittern, Dow process, Steaming out process for the manufacture of bromine. Recovery of magnesium, magnesium metal from sea water, 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. 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, Antibiotic compounds from sponges, Cephalosporins and Fish and Shellfish toxins**.** Chromatographic methods: Gas liquid and high performance liquid chromatograph Basic principles and application to marine samples**.**Spectroanalytical methods: Photometry and Spectrophotometry, Fluorimetry, Flame photometry, Atomic absorption spectrophotometry, Flameless AAS and Inductively coupled plasma emission spectrometry - Basic principles, instrumentation and applications in the analyses of marine samples.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	Lectures/ Tutorials/ assignments/self study.	
References/ Readings	1. A text book of qualitative Inorganic Analysis including Elementary Instrumental analysis, Vogel - 1978. The English Language book society. 2. Standard methods for the examination of water and waste water analysis (22nd edition), 2012. Rice, E.W and Bridgewater L. American Public health association, Washington DC. 3. Methods of seawater analysis, 1983 - Grosshoff, Verlag Chemie, Weinneim. 4. Manual for geochemical analysis of marine sediments and suspended particulate matter, 1992 - Loring and Rantala, Earth Science Review. 5. Chemical Oceanography, 1975 – Riley, J.P and Skirrow, G (eds.), Vol. 3, 1975. Academic Press, London. 6. Environmental Chemistry, 1995 - Anil Kumar De, Wiley Eastern Limited and New age international limited, New Delhi. 7. Marine drugs: chemical and Pharmaceutical aspects. In Chemical Oceanography - H.W. Young Y. Shimizu, In Chemical Oceanography, volume 4, Riley, J.P, and Chester, G (eds.). 8. Marine natural products, 1983 - Scheuer, P.J (ed), Chemical and Biological prospective, Academic Press, London. 9. Marine natural products, 1973 - Scheuer, P.J. Academic Press, London. 10. Quantitative analysis, 2001 - Day, R.A and Underwood, A. L .Prentice-Hall of India, New Delhi. 11. Instrumental methods of Chemical analysis, 4th edition. 1981 - Ewing, G.W., Mc Graw Hill.	
Learning Outcomes	1. These studies would help for accurate measurement of chemical parameters by taking care of necessary precautionary steps during the chemical analyses. 2. Different techniques used for desalination of sea water and inorganic and organic chemicals were known. 3. Pharmacological actions of many drugs obtained from the sea are understood. 4. Instruments used for chemical analyses of sea water and their working principles are well known.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 267 **Title of the Course: Analytical Chemistry of Sea water and Instrumental Techniques Practical**
Number of Credits: 02
Effective from AY: June, 2018-19

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent.	
Objective:	1. The chemical analysis of water provides considerable insight into the health of oceans. 2. The analyses of trace metals in sea water helps in understanding of water's interactions with Earth's geologic materials, and given insight into the impact of human activities on water bodies. 3. The bulk analyses of metals in sediment gives information about the total metal content in a particular environment and it does not give information about the speciation. 4. The sequential extraction procedure described in this course provides an insight into the speciation of a particular element in an environment and their predominant form in the marine environment.	
Content:	**Module – I** 1. Pre concentration of sea water for estimation of dissolved trace metals by AAS technique. (8 hrs; Ref 1, 2, 3, 4) 2. Digestion of particulate matter for estimation of trace metals (6 hrs; Ref 5) 3. Estimation of dissolved and particulate Mn in seawater by Flame AAS method. (6 hrs; Ref 2, 3) 4. Estimation of dissolved and Particulate Co in seawater by Flame AAS method (5 hrs; Ref 2, 3) 5. Estimation of dissolved and particulate Fe in seawater by Flame AAS method (5 hrs; Ref 2, 3) **Module II** 1. Sediment digestion. (10 hrs; Ref 5) 2. Estimation of Mn in sediments by Flame AAS method. (5 hrs; Ref 2, 3, 4, 5) 3. Estimation of Co in sediments by Flame AAS method. (5 hrs; Ref 2, 3, 4, 5) 4. Estimation of Fe in sediments by Flame AAS method. (5 hrs; Ref 2, 3, 4, 5) 5. Speciation of metals in sediments (Exchangeable and carbonate bound metals) (5 hrs; Ref 5)	24 hours 24 hours
Pedagogy:	Lectures/ Demonstations/ Lab experiments.	
References/ Readings	1. Standard methods for the examination of water and waste water analysis (22nd edition), 2012. Rice, E.W and Bridgewater L. American Public health association, Washington DC. 2. Analytical chemistry of seawater, 1975 – Riley J. P. In Chemical Oceanography, J.P. Riley and G. Skirrow (eds.), Vol. 3, Academic Press, London. 3. Methods of Seawater analysis, 1983 – Grasshoff K., M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim, 419. 4. Manual for geochemical analysis of marine sediments and suspended particulate matter, 1977 – Loring, D. H. and Rantala, R. T. T., Fish. Mar. Serv. Dev. Technical Report 700.	
Learning Outcomes	1. The results of metal analyses of seawater samples are used to estimate the current levels of different trace metals in sea water. This would help in assessing the quality of water for sea life. 2. The results of speciation of metals in sediments give an insight into a particular metal and its association with different fractions of sediment components and this would help in un understanding the major form in which a particular metal is associated with a particular fraction of sediment.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 268 **Title of the Course: Aquaculture**
Number of Credits: 04
Effective from AY: June, 2018-19

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 focuses on provision of basic concepts of farming of aquatic organisms. This also educates students to learn different methods of culture, involving preparation of pond to harvesting. Further, it also provides an insight on the national and international status.

Content:	Principles 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. Shrimp aquaculture, types of culture practices, traditional, modified traditional, extensive, modified extensive, semi intensive and intensive, 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. 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.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/ Readings	1. Stickney, R. R. 2009. Aquaculture: An Introductory Text. 2nd edition. CABI. 304 pages 2. Parker, R. 2011. Aquaculture Science. 3rd Edition. Cengage Learning. 672 pages 3. Aquaculture, 1989 – Pillai, T.V.R. 4. Fish and fisheries of India, 1982 – Jhingran, V.G., Hindustan Publ. Corp. India Ltd. New Delhi 5. Diseases of Marine animals – Marine Ecology (Vol 4), 1983 – Kinne, O., Wiley 6. Crustacean aquaculture, 1983 Mckey, J.P. CRC series. 7. Aquaculture, 1972 – Bardach,J. E, Wiley-Inter-science 8. Prawn and prawn fisheries of India, 1976 – Kurian, C.V. & Sebastian, V.O. Hindustan Pub. Corp. 9. Environmental management for aquaculture, 1998 – Midlen, A., Springer, Netherlands 10. Nutrition and feeding of fish, 1999 – Lovell, T. Springer Science & Business Media	
Learning Outcomes	Provision of knowhow to take up culture of aquatic organisms, harvesting, diseases identification, prophylactic measures, harvesting and marketing.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 269 Title of the Course: Aquaculture Practical
Number of Credits: 02
Effective from AY: June, 2018-19

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 aims to identify the cultivable species, their reproductive biology and methods of estimation of water quality parameters for cultivation. It also provides an exposure to the students for the demonstration of commercial practices of culture and hatchery practices.	
Content:	**Module – I** 1. Methods of estimation of dissolved oxygen, BOD, suspended solids, dissolved and particulate organic carbon and ammonia (14 hrs; Ref 1& 2) 2. Identification of cultivable fishes of shrimps, mussels, oysters, fish, crabs and sea weeds (4 hrs, Ref 3) 3. Reproductive system of shrimp (2 hrs; Ref 4), 4. Identification of larval stages of shrimp of commercial importance (4 hrs; Ref 3). **Module – II** 1. Visit to shrimp hatchery and grow out farms for demonstrations (12 hrs, Ref 3 & 4) 2. Fabrication of biological filter in aquarium tank (6 hrs, Ref 5) 3. Fabrication of raft, transplantation of spat for mussel culture (6 hrs).	24 hours 24 hours
Pedagogy:	Field visits, laboratory analysis and identification	

References/ Readings	1. Methods of Seawater Analysis, 1983, 1999 – Grasshoff, K., Ehrhardt, M. and Kremling, K.;Verlag Chemie, Weinheim. 2. A Manual of Chemical and Biological Methods for Seawater Analysis, 1984 – Parsons, T. R., Maita, Y. and Lalli, C. M.; Pergamon Press, Oxford. 3. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, *1988b* - Carpenter K.E. & Niem V.H. *Volume 2.Cephalopods, crustaceans, holothurians and sharks*. (Food and Agricultural Organization, Rome), pp. 687-1396. 4. Crustacean aquaculture, 1983 Mckey, J.P. CRC series. 5. Design and Selection of Biological Filters for Freshwater and Marine Applications, 8-11 November 2004, Honolulu, Hawaii, Edited by C. S. Lee Volume 34, Issue 3, Pages 141-420	
Learning Outcomes	Provides scope to understand various biological aspects of cultivable species and on sight experience of the operation of hatchery and culture systems.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 270 **Title of the Course: Physical Oceanography II**
Number of Credits: 01
Effective from AY: June, 2018-19

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent.	
Objective:	Students with any branch in science at their graduation level are eligible to get admission to PG in Marine Science. Ocean, being a dynamic ecosystem, to know the biology, geology and chemistry of the Ocean, it is imperative to know different physical process responsible to drive the system.	
Content:	Equipment used for physical oceanographic studies: Mechanical bathythermograph, Expendable bathythermograph, Reversing thermometers, CTD, Current meter, Acoustic Doplar Current Profiler (ADCP), Autosal. Equipment used for atmospheric studies: Psycho meter, anemometer, radio sonde, sun-photometer, Radiation meter, Automatic Weather Station - Research vessels: O.R.V. Sagar Kanya, R.V. Sagar Sampada.	12 hours
Pedagogy:	The course is being taught using the conventional method of class room teaching using chalk and board. However, after each module an integral picture is drawn to them through power point presentation. In addition students are given seminar topic related to the course.	
References/ Readings	1. The Ocean: Their Physics, Chemistry and Biology, 1962 - Sverdrup, H.U., Johnson, M.W. and Flemming, R.H., Asia Publ. House, New Delhi. 2. Descriptive Physical Oceanography: An Introduction, 1989 - Pickard, G.B. and Emery, W.J., Pergamon press, U.K. 3. Principles of physical oceanography, 1966 - Pierson, W.J. and Newmann, G.S., Prentice Hall, Inc., New Jersey, U.S.A.	
Learning Outcomes	Getting a larger picture of different equipments necessary for Physical Oceanographic and atmospheric studies	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 271 **Title of the Course: Physical Oceanography Practical II**
Number of Credits: 01
Effective from AY: June, 2018-19

Prerequisites for the course:	Degree of Bachelor of Science of this University or an examination of any other University recognized as equivalent.
Objective:	Delineate and identify regions of a) watermasses, b) Most efficient sound channel in sea c) estimate ocean currents and measure atmospheric parameters.

Content:	1. Identification of water masses and determination of stability of water column using T-S diagram (6hrs; 1-4) 2. Estimation of sound speed and determination of SOFAR channel in different parts of the world ocean (6hrs; Ref 1, 4) 3. Analysis of physical oceanographic processes from Horizontal sections using in-situ data (3hrs) (Ref 2) 4. Computation and Analysis of dynamic topography (6hrs; Ref 2, 5) 5. Measurements of atmospheric pressure, humidity, minimum and maximum temperature, computation of absolute humidity, specific humidity – Mixing ratio (3hrs; Ref 7) 6. Field observations of physical oceanographic parameters-use of meteorological instruments (6hrs; Ref 7, 8)	24 hours
Pedagogy:	Tutorials/assignments/practical/field study	
References/ Readings	1. Seawater: Its Composition, Properties and Behaviour, 1995 - Second Edition, Open University Press, 2. Ocean Circulation, 2001 - Second Edition, Open University Press, Walton Hall, Milton Keynes, MK76AA, UK 3. Algorithms for computation of fundamental properties of seawater, 1983. UNESCO TECHNICAL PAPERS IN MARINE SCIENCE, Endorsed by UNESCO/SCOR/ICES/IAPSO/ Joint Panel on Oceanographic Tables and Standards and SCOR Working Group 51, Unesco, Place de Fontenoy, 75700, Paris, France 4. Principles of physical oceanography, 1996 – Pierson, W.J. and Newmann, G.S., Prentice Hall Inc., New Jersey, U.S.A.. 5. Introduction to Dynamic Oceanography, 1983 - Pond, S. and Pickard, G.H., Pergamon Press, U.K. 6. Tropical Pacific near-surface currents estimated from altimeter, wind, and drifter data. 1999 - Gary S. E. Lagerloef, Gary T. Mitchum, Roger B. Lukas, Pearn P. Niiler., Journal of Geophysical Research, Volume 104, Issue C10, pages 23313–23326. 7. Meteorology Today: An introduction to weather, climate and the environment (2^{nd} edition), 1985 - Ahrens, St. Paul, West Publ. House. 8. Meteorology-Understanding the atmosphere, 2012 - Steven A A	
Learning Outcomes	Detect watermasses. Understand the importance of sound in sea and know its implications for underwater communication/ detection of objects. Know ocean processes along surface and study ocean circulation. Measure atmospheric parameters.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 272 **Title of the Course: Marine Chemistry II**
Number of Credits: 01
Effective from AY: June 2018-19

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 develops concepts about the chemistry of the marine environment that concerns the study of the properties and interactions of the substances present in the marine environment.	
Content:	Micro-nutrient elements (P, N and Si) in seawater – Forms in seawater, distribution and cycle, N:P ratios – Stoichiometry of the uptake and regeneration of the nutrient elements and of oxygen – Chemical oceanography of the seas around India – Instruments used in chemical oceanography. Atmospheric chemistry and air-sea interactions – Composition of the atmosphere, steady state or equilibrium, sources of gases in the atmosphere, reactivity of trace gases in the atmosphere, acid rain, ozone hole; chemistry of sea surface microlayer – Origin, thickness and collection of surface material, properties of the sea surface micro-layer.	12 hours
Pedagogy:	Lectures/ tutorials/ assignments/ self-study	

References/ Readings	1. Introduction to Marine Chemistry, 1971 – Riley, J.P. and Chester, R., Academic Press. 2. Chemical Oceanography (Vol.1, 2, 3 & 8), 1975 – Riley, J.P. & Skirrow, G., Academic Press. 3. Marine Chemistry, 1969 – Horne, R.A., Wiley-Interscience 4. Seawater: Its composition, properties & behaviour, 1989, 1995, 2004 – The Open University. 5. Marine Chemistry (Vol.2), 1970 – Martin, D.F., Marcel Dekker, NY. 6. Tracers in the Sea, 1982 – Broecker and Peng., Lamont-Doherty Geological Observatory, NY. 7. Marine Geochemistry, 1990, 2000 – Chester, R., Blackwell Science. 8. Chemical Oceanography, 1992 – Millero, F. J. and Sohn, M.L., CRC Press. 9. Dynamic processes in the chemistry of the upper ocean, 1986 - Burton et al., Plenum Press. 10. The chemistry of the Atmosphere and Oceans, 1978 – Holland, H.D., Wiley. 11. An Introduction to Environmental Chemistry, 1996 – Andrews et al., Blackwell science. 12. Environmental Chemistry, 1994 - De, A.K., Wiley – Eastern Ltd. 13. Geosphere – Biosphere Interactions and Climate, 2001 – L.O.Bengtsson and C.U.Hammer., Cambridge University Press. 14. Oceanography of the Indian Ocean, 1992 – B. N. Dessai (Ed.), AA Balkema. 15. Chemical Oceanography of the Indian Ocean, North of Equator. 1984, Sengupta and Naqvi, Deep Sea Res. 31A, 671-706. 16. Chemical Oceanography, 1996, 2006 – F. J. Millero, CRC Press. 17. The Sea Surface and Global Change, 1997, 2005 – P.S. Liss and R. Duce., Cambridge University Press. 18. Ocean Biogeochemistry: The role of the ocean carbon cycle in Global change, 2003 – M.J.R. Fasham, Springer. 19. An Introduction to Marine Biogeochemistry, 2nd edition, 2009 – S.B.Libes, Wiley. 20. Marine Chemistry and Geochemistry, 2010 – K. K. Turekian, Academic Press. 21. An Introduction to the Chemistry of the Sea, 2nd edition, 2013 – M.E.Q. Pilson, Cambridge University Press.	
Learning Outcomes	1. Provide a comprehensive understanding of the properties and interactions of the substances present in the marine environment. 2. Explain the key processes operating in the marine environment. 3. Explain the importance of dissolved O_2, the marine carbon cycling and the CO_2 problem. 4. Explain the biogeochemical cycling of the nutrients from the perspective of the global biogeochemical cycling of elements.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 273 Title of the Course: Marine Chemistry Practical II
Number of Credits: 01
Effective from AY: June 2018-19

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 Seawater.	
Content:	1. Spectrophotometric determination of dissolved inorganic phosphate in seawater by ammonium molybdate – ascorbic acid method (6 hrs; Ref 1) 2. Spectrophotometric determination of nitrite in seawater by sulphanilamide – diamine method (6 hrs; Ref 1) 3. Spectrophotometric determination of nitrate in seawater by reduction to nitrite using copper – coated cadmium reduction column (6 hrs; Ref 1) 4. Spectrophotometric determination of ammonia in seawater by indophenol blue method (6 hrs; Ref 1) 5. Spectrophotometric determination of dissolved inorganic silicate in seawater by ammonium molybdate – ascorbic acid – oxalic acid method (6 hrs; Ref 1)	24 hours
Pedagogy:	Laboratory experiments/ field studies	
References/ Readings	1. Methods of Seawater Analysis, 1983, 1999 – Grasshoff, K., Ehrhardt, M. and Kremling, K.; Verlag Chemie, Weinheim. 2. Instrumental Methods of Chemical Analysis, 1981 – Ewing, G. W.; McGraw-Hill, New York.A 3. Manual of Chemical and Biological Methods for Seawater Analysis, 1984 – Parsons, T. R., Maita, Y. and Lalli, C. M.; Pergamon Press, Oxford.	

Learning Outcomes	1. Develop analytical skills to determine the concentrations of micro-nutrient elements (P, N and Si) in seawater/aqueous systems. 2. Apply techniques to seawater/natural waters to study the biogeochemistry of the marine environment/aquatic systems.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 274 **Title of the Course: Marine Biology II**
Number of Credits: 01
Effective from AY: June, 2018-19

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 focuses on provision of basic concepts of marine biological and ecological processes. This also educates students to learn different aspects of food chains and their coupling in the marine environments.	
Content:	Marine productivity - heterotrophic processes and pathways, herbivory and grazing, zooplankton sampling, constraints, methods of biomass estimation, ontogeny and vertical migrations, mud bank formation, processes and fisheries.	12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/ Readings	1. Marine Biology. 8th Edition – 2009 Castro, P. and Huber, M. McGraw Hill Education. 461 pp. 2. Introduction to Marine Biology. 4th Edition. – 2012, Krleskint, G., Turner, R., Small, J., Cengage Learning. 576 pp 3. Biological oceanography 1999 – Lalli, C.M., Elsevier Ltd. 4. Methods in Marine Zooplankton Ecology, 1984 Omori, W. and Ikeda, T. Wiley 5. The Invertebrates (3rd Edn.), 1986 – Barnes, R.S. K. Blackwell Science 6. Zooplankton Methodology Manual, 2000 - Harris, R., Wiebe, P., Lenz, J., Skjoldal, H.R., Huntley, M. (Eds), ICES Academic Press, San Diego, pp. 68	
Learning Outcomes	Provision of knowhow to marine biological processes related to secondary production and fisheries.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 275 **Title of the Course: Marine Biology Practical II**
Number of Credits: 01
Effective from AY: June, 2018-19

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 focuses on some of the morphological features of the marine organisms for the purpose of identification.	
Content:	1. Morphometric measurements and meristic counts of the Indian Mackerel,*Rastrelliger kanagurta* and elasmobranchs (4 hrs; Ref 3, 4, 5) 2. Identification of few commonly occurring teleosts (ray-finned fishes) and their biological characteristics (8 hrs; Ref 3, 4, 5) 3. Identification of brachyuran crabs using morphology and gonopod characteristics, sex determination and their biological importance (6 hrs; Ref 1) 4. Identification of prawns and shrimps using external characteristics, sex determination and biological aspects (6 hrs; Ref 1)	24 hours
Pedagogy:	Identification of marine fauna and fish morphometry	

References/ Readings	1. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific, *1988b* - Carpenter K.E. & Niem V.H. *Volume 2.Cephalopods, crustaceans, holothurians and sharks.* (Food and Agricultural Organization, Rome), pp. 687-1396. 2. FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. *1999a* - Carpenter K.E. & Niem V.H., *Volume 3. Batoid fishes, Chimaeras and bony Fishes Part 1 (Elopidae to Linophrynidae)*. (Food and Agricultural Organization, Rome), pp. 1397-2068. 3. FAO species identification guide for fishery purposes. The living marine resources of 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. 4. 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. 5. 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.	
Learning Outcomes	Provides basic information towards the identification of few marine groups.	

Programme: M.Sc. (Marine Sciences)
Course Code:MSO 276 **Title of the Course: Environmental Impact Assessment**
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course	Students who have undergone courses of semester I of Marine Sciences.	
Objective	This course introduces concept of environmental impact assessment.	
Content	Environmental impact assessment (EIA) - Nexus between development and environment – Socio–economic impacts - purposes of EIA - aid to decision-making - formulation of development actions - sustainable development - EIA in project planning and implementation - EIA process - evaluation of proposed actions - scoping EIA methodologies - impact prediction- mitigation measures - monitoring - Environment Management Plan - planning - selection of appropriate procedures.	12 hours
Pedagogy	Lectures / Seminars involving presentation of environmental impact assessment studies carried out at national and international levels.	
References / Readings	1. Introduction to environmental impact assessment 2005, Glasson J., Therivel R., Chadwick A, Routledge, Taylor & Francis Group, London and New York. 2. Methods of Environmental Impact Assessment 2009, Morris P., Therivel R., 3rd edition, Routledge, Taylor & Francis Group, London and New York. 3. Methods of Environmental Impact Assessment 2001, Morris P., Therivel R., 2nd edition, Spon Press, Taylor & Francis Group, London and New York. 4. Environmental Impact Assessment 2011, Eccleston C. H., CRC Press, Taylor & Francis Group.	
Learning Outcomes	1. Ability to carry out environmental impact assessment study. 2. A potential candidate for recruitment in the EIA consultancy firms.	

Programme: M.Sc. (Marine Sciences)
Course Code:MSO 277 **Title of the Course: Environmental Impact Assessment Practical**
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course	Students who have undergone courses of semester I of Marine Sciences.
Objective	This course introduces field survey, sampling and experiments to assess impact on the environment.

Content	1. Introduction to national and international standard values for ambient air, noise, water, sediments and industrial effluents (4 hrs; Ref 1,2) 2. On board trawler field trip to an estuary to get familiar with field study methods for collection of water, sediment and biological samples (10 hrs; Ref 3) 3. Determination of total dissolved solids in water (5 hrs; Ref 4, 5) 4. Determination of total suspended matter in water (4 hrs; Ref 6) 5. Determination of biogenic silica from sediments (6 hrs; Ref 7, 8) 6. Comparison of determined data with the national standard value (4 hrs; Ref 1, 2) 7. Analysis of environmental impact assessment reports available (4 hrs; Ref 1, 2)	24 hours
Pedagogy	Field survey and sampling / Laboratory experiments / Interpretations	
References / Readings	1. Environmental standards for ambient air, automobiles, fuels, industries and noise. Central pollution control board, Ministry of environment and forests, India, July 2000. 2. Standards and Thresholds for impact assessment, volume 3, Environmental protection in the European Union, 2008, Schmidt M., Glasson J., Emmelin L., Helbron H., Springer-Verlag Berlin Heidelberg. 3. Methods of seawater analysis, 1983 - Grasshoff K., M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim, 419. 4. Sokoloff V.P. (1933) Water of crystallization in total solids of water analysis. Industrial and Engineering Chemistry, 5:336. 5. Howard C.S. (1933) Determination of total dissolved solids in water analysis. Industrial and Engineering Chemistry, 5:4. 6. Liu D., Fu D., Xu B., Shen C. (2012) Estimation of total suspended matter in the Zhujiang (Pearl) River estuary from Hyperion imagery. Chinese Journal of Oceanology and Limnology 30:16-21. 7. Mortlock R.A., Froelich P.N. (1989) A simple method for the rapid determination of biogenic opal in pelagic marine sediments. Deep-Sea Research, Part A, 36:1415-1426. 8. DeMaster D.J. (1979) The marine budgets of silica and ^{32}Si. Ph.D. Dissertation, Yale University, 308pp.	
Learning Outcomes	1. Ability to conduct field survey and sampling for environmental impact assessment study. 2. Conducting laboratory experiments and interpretation of data.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 278 **Title of the Course: GIS Applications in Marine Science Practical - I**
Number of Credits: 01
Effective from AY: June, 2018-19

Prerequisites for the course:	Students who have undergone semester I of Marine Sciences.	
Objective:	To use GIS techniques in the field of oceanography / meteorology	
Content:	1. GIS, GIS software familiarization and image properties (8 hrs; Ref 1&2) 2. Data acquisition and integration in GIS software (6 hrs; Ref 1&3) 3. Image edge detection, Transects, spectra and time series images (6 hrs; Ref 3) 4. Contrast stretching, Colour palettes, smoothing satellite images(4 hrs; Ref 3 & 4) 5. Digitizing Vector maps (6 hrs; Ref 6)	24 hours
Pedagogy:	Tutorials/ assignments/practicals/field study	
References/ Readings	1. Practical Handbook of Digital Mapping: Terms and Concepts Arlinghaus, 1994 Sandra L., - CRC Press.0-8493-0131-9 2. Coastal and marine geospatial technologies. 2010. Ed. David R Green, Springer, ISBN 978-1-4020-9719-5 3. *Remote Sensing Handbook for Tropical Coastal Management*. Coastal Management Source books 3.2004.Edmund P. Green, Peter J. Mumby, Alasdair J. Edwards and Christopher D. Clark, UNESCO, Paris. 4. Principals of Geographic information systems- An introductory text book, 2009 - Eds :ottoHuisman and Roff A. de By (ed.) International Institute for Geo-Information and Earth Observation, Netherlands. 5. Essentials of Geographic Information Systems, 2011 - Jonathan Campbell, Michael Shin	

	Publisher: Flat World Knowledge 6. ***GRASS GIS: a multi-purpose Open Source GIS***. Environmental Modelling & Software. 2012 - Neteler, M., Bowman, M.H., Landa, M. and Metz, M.	
Learning Outcomes	Characterize data into line/ point / polygon feature. Geo-reference and image, integrate data into GIS, Digitization of Vector maps, identification of line from specific distance from high tide line,	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 279 **Title of the Course: GIS Applications in Marine Science Practical -II**
Number of Credits: 01
Effective from AY: June, 2018-19

Prerequisites for the course:	Students who have undergone semester I of Marine Sciences.	
Objective:	To use GIS techniques in the field of oceanography / meteorology	
Content:	1. The Importance of Acquiring satellite Images of the Appropriate resolution (4 hrs; Ref 3 & 5) 2. CRZ mapping (6 hrs; Ref 2,3 &4) 3. Estimating coral bleaching potential from SST (6 hrs; Ref 1 & 3) 4. Mangrove Leaf-Area Index (LAI) using imageries (6 hrs; Ref 1&3) 5. Geospatial Analysis of Vector data (8 hrs; Ref6)	24 hours
Pedagogy:	Tutorials/ assignments/practicals/field study	
References/ Readings	7. Practical Handbook of Digital Mapping: Terms and Concepts Arlinghaus, 1994 Sandra L., - CRC Press.0-8493-0131-9 8. Coastal and marine geospatial technologies. 2010. Ed. David R Green, Springer, ISBN 978-1-4020-9719-5 9. *Remote Sensing Handbook for Tropical Coastal Management*. Coastal Management Source books 3.2004.Edmund P. Green, Peter J. Mumby, Alasdair J. Edwards and Christopher D. Clark, UNESCO, Paris. 10. Principals of Geographic information systems- An introductory text book, 2009 - Eds :ottoHuisman and Roff A. de By (ed.) International Institute for Geo-Information and Earth Observation, Netherlands. 11. Essentials of Geographic Information Systems, 2011 - Jonathan Campbell, Michael Shin Publisher: Flat World Knowledge 12. *GRASS GIS: a multi-purpose Open Source GIS.*Environmental Modelling & Software. 2012 - Neteler, M., Bowman, M.H., Landa, M. and Metz, M.	
Learning Outcomes	Utilization of appropriate resolution for raster image analysis, Delineation of specific zones such as CRZ and the features/parts of feature within that zone, estimating possible impact of ocean warming on corals, capture vegetation in coastal zone.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 280 **Title of the Course: Marine Chemistry Practical III**
Number of Credits: 01
Effective from AY: June 2018-19

Prerequisites for the course:	Students who have undergone semester I of Marine Sciences.
Objective:	This course deals with the Analytical Chemistry of Seawater.

Content:	1. Determination of sulphate in seawater gravimetrically by precipitation of $BaSO_4$ using $BaCl_2$ in the presence of picric acid (6 hrs; Ref 1) 2. Determination of thiosulphate in seawater by iodometric titration with the removal of sulphide using zinc acetate (6 hrs; Ref 1) 3. Determination of bromide in seawater by oxidizing to bromate using hypochlorite followed by iodometric titration (6 hrs; Ref 1) 4. Spectrophotometric determination of urea in seawater by diacetyl monoxime – semicarbazide method (6 hrs; Ref 1) 5. Spectrophotometric determination of carbohydrates in seawater by 3- methyl-2-benzothiazoline hydrazone (MBTH) method (6 hrs; Ref 1)	24 hours
Pedagogy:	Laboratory experiments/ field studies	
References/ Readings	1. Methods of Seawater Analysis, 1983, 1999 – Grasshoff, K., Ehrhardt, M. and Kremling, K.; Verlag Chemie, Weinheim. 2. Organic Reaction Mechanisms, 1997 - Knipe, A. C. and Watts, W. E., John Wiley and Sons, New York. 3. A Manual of Chemical and Biological Methods for Seawater Analysis, 1984 – Parsons, T. R., Maita, Y. and Lalli, C. M.; Pergamon Press, Oxford. 4. Aquatic Chemistry, 1981, 1996 – Stumm, W. and Morgan, J. J., John Wiley and Sons, New York. 5. Aquatic Surface Chemistry, 1987 – Stumm W., John Wiley and Sons, New York. 6. Practical Estuarine Chemistry, 1985 - Head, P.C., Cambridge University Press, Cambridge. 7. A simplified resorcinol method for direct spectrophotometric determination of nitrate in seawater, 2006 - Zhang, J. Z. and Fischer, C. J. Marine Chemistry, 99, 220 – 226. 8. Phosphorus release from lake sediments: effects of pH, temperature and dissolved oxygen, 2014 - Wu, Y., Wen, Y., Zhou, J. and Wu, Y., KSCE Journal of Civil Engineering, 18, 323 – 329. 9. The effect of pH on the release of phosphorus from Potomac estuary sediments: Implications for blue-green algal blooms, 1991 - Seitzinger, S. P., Estuarine, Coastal and Shelf Science, 33, 409-418. 10. Emission of carbon dioxide from a tropical estuarine system, Goa, India, 2001 - Sarma, V.V.S.S., Dileep Kumar, M. and Manerikar, M., Geophysical Research Letters, 28, 1239-1242. 11. Chemistry of dissolved inorganic carbon in estuarine and coastal brackish waters, 1975 - Mook, W.G. and Koene, B.K.S., Estuarine, Coastal and Marine Science 3, 325-336. 12. Sorption model for dissolved and leachable particulate Al in the Great Ouse estuary, England, 2012 - Upadhyay, S., Aquatic Geochemistry, 18, 243-262.	
Learning Outcomes	1. Develop analytical skills to determine the concentrations of various chemical parameters, such as sulphate, thiosulphate, bromide, urea and carbohydrates in seawater/aqueous systems. 2. Apply techniques to seawater/natural waters to study the biogeochemistry of the marine environment/aquatic systems.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 281 **Title of the Course: Marine Chemistry Practical IV**
Number of Credits: 01
Effective from AY: June 2018-19

Prerequisites for the course:	Students who have undergone semester I of Marine Sciences.
Objective:	This course deals with the Analytical Chemistry of Seawater and laboratory simulations.

Content:	1. Spectrophotometric determination of nitrate in seawater by resorcinol method (6 hrs; Ref 2, 7) 2. Spectrophotometric determination of ammonia in seawater by oxidation method (6 hrs; Ref 3) 3. Laboratory experiments to study variation of pH on river water-seawater interactions (mixing experiments followed by pH measurements by pH meter) (6 hrs; Ref 1, 6, 11) 4. Determination of dissolved Al spectrophotometrically by pyrocatechol violet method (6 hrs; Ref 1) 5. Reactivity of dissolved Al with particulate material: laboratory simulations (mixing experiments followed by determination of dissolved Al spectrophotometrically by pyrocatechol violet method) (6 hrs; Ref 1, 5, 12)	24 hours
Pedagogy:	Laboratory experiments/ field studies	
References/ Readings	1. Methods of Seawater Analysis, 1983, 1999 – Grasshoff, K., Ehrhardt, M. and Kremling, K.; Verlag Chemie, Weinheim. 2. Organic Reaction Mechanisms, 1997 - Knipe, A. C. and Watts, W. E., John Wiley and Sons, New York. 3. A Manual of Chemical and Biological Methods for Seawater Analysis, 1984 – Parsons, T. R., Maita, Y. and Lalli, C. M.; Pergamon Press, Oxford. 4. Aquatic Chemistry, 1981, 1996 – Stumm, W. and Morgan, J. J., John Wiley and Sons, New York. 5. Aquatic Surface Chemistry, 1987 – Stumm W., John Wiley and Sons, New York. 6. Practical Estuarine Chemistry, 1985 - Head, P.C., Cambridge University Press, Cambridge. 7. A simplified resorcinol method for direct spectrophotometric determination of nitrate in seawater, 2006 - Zhang, J. Z. and Fischer, C. J. Marine Chemistry, 99, 220 – 226. 8. Phosphorus release from lake sediments: effects of pH, temperature and dissolved oxygen, 2014 - Wu, Y., Wen, Y., Zhou, J. and Wu, Y., KSCE Journal of Civil Engineering, 18, 323 – 329. 9. The effect of pH on the release of phosphorus from Potomac estuary sediments: Implications for blue-green algal blooms, 1991 - Seitzinger, S. P., Estuarine, Coastal and Shelf Science, 33, 409-418. 10. Emission of carbon dioxide from a tropical estuarine system, Goa, India, 2001 - Sarma, V.V.S.S., Dileep Kumar, M. and Manerikar, M., Geophysical Research Letters, 28, 1239-1242. 11. Chemistry of dissolved inorganic carbon in estuarine and coastal brackish waters, 1975 - Mook, W.G. and Koene, B.K.S., Estuarine, Coastal and Marine Science 3, 325-336. 12. Sorption model for dissolved and leachable particulate Al in the Great Ouse estuary, England, 2012 - Upadhyay, S., Aquatic Geochemistry, 18, 243-262.	
Learning Outcomes	1. Develop analytical skills to determine the concentrations of various chemical parameters, such as nitrate, ammonia and Al in seawater/aqueous systems. 2. New analytical technique for nitrate and ammonia is adopted. 3. Laboratory simulations are conducted to understand the mechanisms of reactions. 4. Apply techniques to seawater/natural waters to study the biogeochemistry of the marine environment/aquatic systems.	

SEMESTER III

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 361 Title of the Course: Geophysical Fluid Dynamics
Number of Credits: 04
Effective from AY: June, 2018-19

Prerequisites for the course:	Students undergoing course with Physical Oceanography specialization. However, it is flexible to those having interest to learn basics of fluid dynamics.	
Objective:	This course is introduced to impart students an insight into different scales of motion in fluids (which includes both atmosphere and ocean) and how to understand them by applying basic theorems and laws of fluid dynamics.	
Content:	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, rotating frame of reference, Kinematics. Kinematics: Lagrangian and Eulerian methods of description of fluid flow-Lagrangian and Eulerian method- 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. Dynamics - I: equation of continuity and its applications, non-viscous incompressible flow, Eulerian equations of motion, inertial and rotational frames of reference, Coriolis force, irrotational flow, velocity potential, integration of the equations of motion, Bernoulli's theorem and its applications. Dynamics – II: Circulation and vorticity, Stoke's theorem, Kelvin's theorem, Helmholtz theorem, barotropic and baroclinic fluids, absolute and relative circulation; V. Bjerknes circulation theorem and its interpretation, potential vorticity-conservation, Eddy coefficients, Important dimensionless number, Turbulent diffusion; Combination of advection and diffusion, Geostrophic flow and vorticity dynamics, laminar flow of viscous incompressible fluids; Turbulence in stratified flows; Reynold's number and dynamic similarity of flows, physical significance of Reynold's number, low and high Reynold's number.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	Since the above course is theory component which includes basic theory and derivations, total syllabus is taught in the class. However to get a feeling of the application to natural ecosystem, assignments are given to students thus developing the art of presentation and generating a thought process in the students.	
References/ Readings	1. Hydraulics and fluid mechanics, 1985 – Modi, P.N. and Seth., Standard Book House, Delhi. 2. Foundation of fluid mechanics, 1969 – Yuan, S. W., Prentice Hall, New Delhi. 3. An introduction to fluid mechanics, 1967 – Batchelor, G.K., Cambridge Univ. Press, UK. 4. Hydrodynamics, 1975 – Lamb, H., Cambridge Univ. Press, U.K. 5. Introduction to fluid mechanics, 1976 – Rathy, R.K., Oxford and IBH Publ. Co., New Delhi. 6. The physics of marine atmosphere, 1965 – Roll, H.U., Academic Press, London. 7. Atmosphere – Ocean Dynamics, 1982 - Gill, Adrian E, International Geophysics, 30 Academic press, New York.	
Learning Outcomes	Apply the knowledge gained to solve real life problems confronting the environment.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 362 **Title of the Course: Geophysical Fluid Dynamics Practical**
Number of Credits: 02
Effective from AY: June, 2018-19

Prerequisites for the course:	Physical Oceanography, with flexibility to those having interest to learn basics of fluid dynamics.	
Objective:	This is introduced to acquaint students with a hands-on-experience on what they learned in the theory. It involves field based observations and numerical techniques.	
Content:	**Module – I** 1. Kinematics analysis of wind and ocean current – Isotach and isogen analysis and construction of streamline patterns (10 hrs; Ref1) 2. Construction of trajectories of air parcels from successive synoptic charts (8 hrs; Ref1) 3. Computation of divergence and vorticity in horizontal flow (12 hrs; Ref2) **Module – II** 1. Construction of stream lines for simple types of flow (7 hrs; Ref2) 2. Field observations and analysis of Physical Oceanographic parameters of estuarine watersusing conductivity temperature and depth (CTD) instrument (15 hrs; Ref1,3) 3. Analysis of aerosol trajectory using HYSPLIT (HYbrid Single – Particle Lagrangian Integrated Trajectory) model. (8 hrs; Ref4)	24 hours 24 hours
Pedagogy:	This involves field observations (time series) and associated numerical techniques to differentiate different components of vector velocity.	
References/ Readings	1. Introduction to Physical Oceanography, 2008 – Robert H. Stewart, Department of Oceanography Texas , A&M University, Oceanworld.tamu.edu/resources/ocng_ textbook/PDF files/book.pdf 2. Guide to wave analysis and forecasting (2nd edition), 1998 - World Meteorological Organization (WMO- no 702) ISBN-92-63-12702-6, www.wmo.int/pages/prog/amp/mmop/documents/WMO%20No%20702/WMO702.pdf 3. Ocean Circulation and Climate (2nd Ed), 2013 - A 21st Century perspective eds. Siedler, G, Griffies, S, Gould .J, and Church, J, ISBN- 978-0-12-391851-2, Academic press. 4. HYSPLIT- Hybrid Single Particle Lagrangian integrated Trajectory Model, Air Resources Laboratory, http://www.arl.noaa.gov/ . NOAA technical memorandum ERL, ARL-224, Roland R. Draxler and Hess, G.D 5. The physics of marine atmosphere, 1965 – Roll, H.U., Academic Press, London. 6. Atmosphere – Ocean Dynamics, 1982 -- Gill, Adrian E, International Geophysics, 30 Academic press, New York.	
Learning Outcomes	Apply the knowledge gained to solve issues confronting the coastal regions specifically coastal dynamics leading to erosion.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 363 **Title of the Course: Ocean - Atmosphere Coupling and Climate**
Number of Credits: 04
Effective from AY: June, 2018-19

Prerequisites for the course:	Physical Oceanography and Marine Biology
Objective:	To learn exchange of mass and energy across air-sea interface and its role in global climate.

Content:	Wind generation, forces acting on wind, Geostrophic winds, thermal winds. Wind wave generation, scale of interaction, General character of sea surface as a lower boundary of air flow – Geometry of the sea surface – The wind field in the maritime frictional layer. Drag coefficient. General consideration of air sea interaction – Planetary boundary layer - Laminar boundary layer, surface layer and spiral layer. Variation of air sea fluxes with special reference to upwelling – Transfer of heat and water vapour – Determination of air – sea fluxes – Fronts and water masses interaction -Profile method and non profile methods. Energy exchange and global climate – Radiation and its role on tropical circulation – Indian Summer Monsoons: cause, inter-seasonal and intra-seasonal variability,Monsoon Trough, LLJ, Tibetan Low, Mascarenhas High, TEJ, El-nino, La nina. Tropical cyclones: Cyclone structure, Generation, growth and decay. Temperature, pressure field and wind speed and direction. Cyclones in North Indian Ocean, – Instruments used in marine meteorology – Concepts in climatology, fundamental oceanic processes influencing climate – climate change.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	Lectures/Tutorials/ assignments	
References/ Readings	1. Monitoring & prediction of tropical cyclones in Indian Ocean & climate change, 2014 - U. C. Mohanty, M. Mohapptra, O.P Singh, B. K Bandhopadhyay & L. S. Rathore. 2. Hot Spots in the climate system, 2016 - Nakamura H., Isobe A., Minobe S., Mitsudera, H. Nonaka M., Suga, T. (Eds.), Springer. 3. Air Sea exchange of heat and moisture during storms, 1987 - R.S Bortkovskii, Revised English edition by Edward C. Monahan, Springer. 4. The physics of marine atmosphere, 1965 - Roll, H.U., Academic Press, London. 5. The sea: Ideas and observations (Vol.1), 1962 – Hill, M.N.(Ed.), John Wiley & sons, New York. 6. Oceanography for meteorologists, 1945 – Sverdrup, H.U., George Allen & Unwin, London. 7. Principles of physical oceanography, 1996 – Pierson, W.J. and Newman, G., Prentice Hall Inc., New Jersey, U.S.A. 8. Introduction to theoretical meteorology 1959 – Hess, H.L., Holt, Rinehart & Winston, New York. 9. Tropical meteorology (Vol. 1 & 2), 1993 – Asnani, G.C., Asnani Publ., Pune, India. 10. The physics of monsoons, 1992 – Keshavmurthy and Rao, Allied Publ., New Delhi. 11. Climate change, 1995 – Houghton, J.T., Cambridge Univ. Press, U.K. 12. Climate of South Asia, 1997 – Pant and Kumar, John wiley. 13. The Dvorak Tropical Cyclone Intensity Estimation Technique: A Satellite-Based Method that Has Endured for over 30 Years, 2006 - Velden, Christopher, and Co-authors, *Bull. Amer. Meteor. Soc.*, 87, 1195–1210.	
Learning Outcomes	Explain exchange of momentum, and energy and their role in climate. Explain southwest monsoon and tropical cyclones. Generation of waves, El Nino and La Nina.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 364 **Title of the Course: Ocean Atmosphere Coupling and Climate Practical**
Number of Credits: 02
Effective from AY: June, 2018-19

Prerequisites for the course:	Physical Oceanography	
Objective:	To analyze air-sea fluxes and the factors responsible, relationship between SST and southwest Indian monsoon, analyze El Nino and La Nina events	
Content:	**Module – I** 1. Data extraction from global data sets of Short Wave Radiation and analysis of its distribution (6hrs; Ref 1, 2, 3,4) 2. Data extraction from global data sets of Long Wave Radiation and analysis of its distribution (6hrs; Ref 1, 2, 3,4) 3. Data extraction from global data sets of Sensible Heat flux and analysis of its distribution (6hrs; Ref 1, 2, 3,4) 4. Data extraction from global data sets of Latent Heat Flux and analysis of its distribution (6hrs;	24 hours

	Ref 1, 2, 3,4) 5. Estimation of Net heat flux from above extracted data sets and analysis of its distribution (6hrs; Ref 1, 2, 3,4) 6. Analysis of fluxes over Central Pacific during Normal, El-Nino and La Nina events (6hrs; Ref5) **Module – II** 1. Arabian Sea SST and Indian Summer rainfall correlation (6hrs; Ref6) 2. Central Pacific SST and Indian Summer rainfall correlation (6hrs; Ref6) 3. Cyclone intensity estimation using Dvorak technique for satellite images (8hrs; Ref 6,7) 4. Determination and analysis of cyclone tracks in Arabian Sea and Bay of Bengal (6hrs; Ref6) 5. Analysis of annual variations of N and S hemispheric air temperature (4hrs; Ref3)	24 hours
Pedagogy:	Tutorials/ assignments/practicals	
References/ Readings	1. The Physics of marine atmosphere, 1965 –Roll, H.U., Academic Press, London. 2. Oceanography for meteorologists, 1945 –Sverdrup, H.U., George Allen & Unwin, London, U.K. 3. Climate change, 1995 –Houghton, J.T., Cambridge Univ. Press, U.K. 4. Atlas of Surface Marine Data 1994, Volume 1: Algorithms and Procedures, 1994 - A. da Silva, A. C. Young, S. Levitus, No. 6.Department of Commerce, NOAA, NESDIS. 5. Air -sea fluxes from ICOADS: the construction of a new gridded dataset with uncertainty estimate, 2011 - Berry, D. I., and E. C. Kent, International Journal of Climatology, 31, 987 -1001: DOI: 10.1002/joc.2059. 6. Tropical Meteorology, 2005 - Asnani G C. 7. The Dvorak Tropical Cyclone Intensity Estimation Technique: A Satellite-Based Method that Has Endured for over 30 Years, 2006 - . Velden, Christopher, and Co-authors, *Bull. Amer. Meteor. Soc.*, 87,1195–1210.	
Learning Outcomes	Examine statistical relationship between El Nino and southwest Indian Monsoon, Explain spatiotemporal variability of fluxes and the possible governing factors.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 365 **Title of the Course: Marine Pollution**
Number of Credits: 04
Effective from AY: June, 2018-19

Prerequisites for the course:	Marine Biology and Marine Chemistry	
Objective:	1. To understand the type of pollutants discharged into sea as a result of human activities, their sources and impact on marine life. 2. To study the addition of conservative (radioactive pollutants, trace metals and pesticides), non conservative pollutants (Oil and other organic wastes) and nutrient salts, their implications on human health and food resources and commercial interest. 3. Quantification of pollutant studies through suitable indicator organisms. 4. To study monitoring strategies of marine pollution through different approaches and assessment of pollution damage in order to understand	
Content:	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. Oil spills and cleanup: sources, major accidental spills, fate of spilled oil on the sea, consequences	12 hours 12 hours

	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 **a**nd 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. Indicator organisms: Criteria for selection of indicator organism: Quantification of pollution load, basic pre-requisites, response to different pollution load and time integration capacity, Macro algae, crustaceans and mollusks as indicator organisms for monitoring of trace metal pollution; Red tides : distribution, types of poisoning, effects and methods to minimize red tides in the sea. 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.	12 hours 12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/ Readings	1. Chemical Oceanography (Vol: 3), 1975 - Riley J.P and Skirrow, G. (eds.), Academic press, New York. 2. The health of the oceans, 1976 - Goldberg, E.D. UNESCO Press. 3. Marine Pollution, 1986 - Clark, R.B. Oxford science Publications. 4. Quantitative aquatic biological indicators, 1980 - Phillips J.D.H. Applied Science Publishers. 5. Thermal and radioactive pollution, 1994 - Sharma, B.K and Kaur, H. Krishna Prakasham Mandir, Meerut. 6. Water Pollution, 1994 - Sharma, B. K and Kaur, H. Krishna Prakasham Mandir, Meerut. 7. Marine and offshore corrosion, 1985 - Chandler, K.A. Butter Worths, London.	
Learning Outcomes	1. The course helps in understanding the impact of various pollutants on marine ecosystem; it analyses the factors responsible for degradation and suggests suitable corrective measures around the world. 2. To create awareness among student, by information by educating them to safeguard the marine environment 3. The course further identify the factors responsible for causing marine pollution , to suggest policy measures to prevent marine pollution, to create sustainable marine environment and 4. To provide advisory and technical service to government and industry for pollution abatement.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 366 **Title of the Course: Marine Pollution Practical**
Number of Credits: 02
Effective from AY: June2018-19

Prerequisites for the course:	Marine Chemistry and Marine Biology	
Objective:	1. The objective of this course understands the concentration of various pollutants in the seawater and their effect on marine life. 2. The analyses of BOD and COD are used to understand the impact organic pollution on water bodies. 3. Different pollutants like Fluoride and Hydrogen sulphide in sea water it greatly influence the quality of water for marine life including man.	
Content:	**Module – I** 1. Determination of dissolved oxygen in polluted waters. (6 hrs; Ref1) 2. Determination of biochemical oxygen demand in polluted waters. (6 hrs; Ref1) 3. Determination of chemical oxygen demand in polluted waters. (6 hrs; Ref2) 4. Determination of fluoride. (6 hrs; Ref3) 5. Determination of hydrogen sulphide. (6 hrs; Ref3) **Module – II** 1. Pre-concentration of water by solvent extraction method (6 hrs; Ref 5,6,7) 2. Digestion of biological samples for estimation of toxic metals. (6 hrs; Ref8) 3. Estimation of Cd in polluted waters and biological sample. (6 hrs; Ref 5,6,7)	24 hours 24hour

	4. Estimation of Cu in polluted waters and biological samples. (6 hrs; Ref 5,6,7) 5. Estimation of Pb in polluted waters and biological samples. (6 hrs; Ref 5,6,7)	s
Pedagogy:	Demonstations/ Lab experiments.	
References/ Readings	1. Marine chemistry Vol. 1, 1972 - Martin, D.F, . Academic Press, London. 2. Standard methods for the examination of water and waste water analysis (22nd edition), 2012. Rice, E.W and Bridgewater L. American Public health association, Washington DC. 3. Methods of Seawater analysis, 1983 - Grasskhoff, K, M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim. 4. A practical hand book of seawater analysis, 1972 - Strickland, J.D.H, and Parsons, T.R., Fisheries Board of Canada bulletin. (2nd edition). 5. Analytical chemistry of seawater, In Chemical Oceanography, 1975 - Riley, J.P. and Skirrow, G. (eds.), Vol. 3. Academic Press, London. 6. Chemical Analysis. In: Methods in plant Ecology, 1976 - Allen, S. E., Grimshaw, H. M., Parkinson, J. A., Quarmby, C. and Roberts, J.D. 1976. S. B. Chapman (eds.), Blackwell Scientific Publications, Oxford, Chapter 8.	
Learning Outcomes	1. The results of analyses of different pollutants in sea water and marine organisms can be used to assess the effectiveness of existing regulatory activities. 2. These concentrations will be compared with the daily intake of, or exposure to a pollutant by organism/man and it can lead to acceptable concentration of pollutant in organism. 3. These studies would help to regulate the release of a particular pollutant in the marine environment.	

Programme: M.Sc. (Marine Sciences)
Course Code:MSO 367 **Title of the Course: Bioaccumulation and Phytoremediation**
Number of Credits: 03
Effective from AY: June2018-19

Prerequisites for the course	Students undergoing course in any branch of Marine Sciences.	
Objective	This course introduces concept of bioaccumulation of metals and remediation of metal pollution by mangroves.	
Content	Metal sources to marine environment - natural - anthropogenic - metal retention in sediments -role of grain size - organic matter - Fe-Mn oxides - sulphides - Definition and significance of metal speciation - forms of metals - bioavailable - residual - bioavailability of metals -definition - driving factors for desorption of metals from the bioavailable fraction of the sediments - ionic composition – pH – Eh - organic matter degradation – metal toxicity assessment – SQUIRT - RAC.	12 hours
	Bioaccumulation of metals – definition - metal accumulation in benthic biota - Arsenic bioaccumulation in biota of the Sundarban Mangrove Wetland – a case study - Bioaccumulation factor (BAF) - concept of Bioconcentration – Bioconcentration factor (BCA) - harmful effects of bioaccumulation of metals on biota - Biomagnification in trophic levels – risk to human health.	12 hours
	Metal accumulation in mangroves – pneumatophores – leaves - stem - remediation of metal contamination – phytoremediation – application of mangrove species - Translocation factor (TF) - techniques of phytoremediation – Phytoextraction – Rizofiltration – phytovolatilization - phytostabilization, phytodegradation - Rhizodegradation/Phytostimulation - Advantages and disadvantages of Phytoremediation.	12 hours
Pedagogy	Lectures / Assignments / Seminars / Discussion	
References / Readings	1. Trace metals in a tropical mangrove wetland, 2018 Sarkar, S. K., Springer Nature Singapore Pte Ltd. 2. Trace elements in terrestrial environments, 2001 Adriano, D.C., Springer Science+Business Media, LLC. 3. Bioaccumulation in marine organisms, 2002 Neff, J. M., Elsevier Ltd. 4. The biology of mangroves and seagrasses, 2015 Hogarth P. J., Oxford University press. 5. Sequential extraction procedure for the speciation of particulate trace metals, 1979 Tessier, A., Campbell, P. G. C. and Bisson, M., Analytical Chemistry, American Chemical Society.	
Learning Outcomes	1. Understanding of accumulation of metals by biota and mangroves. 2. Knowledge of application of mangroves in remediation of metal pollution.	

Programme: M.Sc. (Marine Sciences)
Course Code:MSO 368 **Title of the Course: Bioaccumulation and Phytoremediation Practical**
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course	Students undergoing course in any branch of Marine Sciences.	
Objective	This course introduces experiments to determine metal concentration in sediments, biota and mangroves to understand metal accumulation process and metal remediation potential of mangroves.	
Content	1. Digestion and chemical speciation of metals in sediments (Exchangeable, carbonate, Fe-Mn oxide, organic/sulphide and residual bound metals) (13 hrs; Ref 3, 4, 5) 2. Estimation of Mn, Co, Ni in sediments by flame AAS method (6 hrs; Ref 1, 2, 3, 4, 5) 3. Digestion of tissues of biota (5 hrs; Ref 5, 6, 7) 4. Estimation of Mn, Co, Ni in biota by flame AAS method (6 hrs; Ref 5, 6, 7) 5. Digestion of mangrove tissues (5 hrs; Ref 5, 8, 9) 6. Estimation of Mn, Co, Ni in mangrove tissue samples (6 hrs; Ref 5, 8, 9)	24 hours
Pedagogy	Field studies / Laboratory experiments / Interpretations	
References / Readings	1. Analytical chemistry of seawater, 1975 – Riley J. P. In Chemical Oceanography, J.P. Riley and G. Skirrow (eds.), Vol. 3, Academic Press London. 2. Methods of seawater analysis, 1983 – Grasshoff K., M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim, 419. 3. Manual for geochemical analysis of marine sediments and suspended particulate matter, 1977 Loring , D. H. and Rantala, R. T. T., Fish. Mar. Serv. Dev. Technical Report 700. 4. Sequential extraction procedure for the speciation of particulate trace metals, 1979 Tessier, A., Campbell, P. G. C. and Bisson, M., Analytical Chemistry, 51(7):844-851, American Chemical Society. 5. Trace metals in a tropical mangrove wetland, 2018 Sarkar, S. K., Springer Nature Singapore Pte Ltd. 6. Temporal and spatial variation on heavy metal concentrations in the bivalve Perna perna (Linnaeus, 1758) on the northern coast of Rio de Janeiro state, Brazil, 2004 Ferreira, G.A., Machado, A.L.S., Zalmin, I.R., Brazilian Archives of Biology and Technology 47:319-327. 7. Heavy metals in Patella caerulea (mollusca, gastropoda) in polluted and non-polluted areas from the Iskenderun Gulf (Mediterranean Turkey), 2010 Yuzereroglu, T. A., Gok, G., Cogun, H. Y., Firat, O., Aslanyavrusu, S., Maruldali, O. and Kargin, F. Environmental Monitoring and Assessment 167(1-4):257-264. 8. 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, 2014, Nath, B., Birch, G. and Chaudhuri, P., Science of the Total Environment 472:1010-1022. 9. Toxicity, growth and accumulation relationships of copper lead and zinc in the grey mangrove Avicennia marina (Forsk.) Vierh, 2002, MacFarlane, G. R. and Burchett, M. D., Marine Environmental Research 54:65-84.	
Learning Outcomes	1. To understand field survey and sampling. 2. Ability to interpret data and link bioavailability with bioaccumulation. 3. To understand phytoremediation process.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 369 **Title of the Course: Aerosol and Climate**
Number of Credits: 03
Effective from AY: June2018-19

Prerequisites for the course:	Students undergoing course in any branch of Marine Sciences.
Objective:	This course is introduced as an attempt to make students understand the significant role of aerosol on regional climate in particular and Global climate in general.

Content:	Introduction to aerosols – Aerosol motion – Stoke's law and setting velocity - Sun photometry – Multi-wavelength radiometer -estimation of aerosol optical depth (AOD)- Brownian motion and diffusion deposition-Brownian coagulation- Angstrom turbidity formula – Particle sizes and functions used to fit aerosol size distribution – The lognormal- gamma and power law functions-aerosol measurement network – ARFI and AERONET- Aerosol water uptake-Solubility and hygroscopicity - Hygroscopicity and cloud condensation nuclei (CCN) activity – Aerosol optical properties and Mie theory for spherical particles. Light absorbing black Carbon (BC) aerosol- Aerosol light scattering-absorption and extinction-Aethalometer - Quartz crystal microbalance (QCM) for size analysis – Identification of planetary boundary layer – In-situ production of aerosol -Shear and turbulence- estimation of Richardson number (Ri) - estimation of heat flux - sensible and latent- maritime and continental aerosol- land and sea breeze - Long range transport of aerosol. Retrieval of aerosol optical depth from satellite data. Estimation of aerosol radiative forcing and atmospheric heating rate- implications to climate - present status of aerosol research in India and in the world. Atmosphere: Chemical and photochemical reactions in the atmosphere. Atmospheric trace constituents: Oxygen, sulphur containingcontaining compounds: sulfur dioxide, dimethyl sulphide, and carbonyl sulphide. Nitrogen containing compounds: nitrous oxide, nitrogen oxides and ammonia. Carbon containing compounds: hydrocarbons, volatile organic compounds, carbon monoxide and carbon dioxide. Halogencontaining compounds: Methyl chloride, methyl bromide. Green house effect/Global warming; biomass burning and air pollution.	12 hours 12 hours 12 hours
Pedagogy:	Since it is a theory component, entire course is taught in the class. However, to get a strong understanding seminar topics, other than from the syllabus are given to students.	
References/ Readings	1. Atmospheric Chemistry and Physics, 2006 - From air pollution to Climate change. Seinfeld. John H; Pandis, Spyros N, John Wiley. 2. Radiation and cloud processes in the atmosphere, 2006 - Theory, Observation and modeling, Kuo-Nan Liou, Oxford University Press. 3. Atmospheric aerosol properties, 2006 - Kondrateyev, K.Y, Ivlev L.S, Krapivin, V.F, Varostos C.A, Springer Praxis Book. 4. An Introduction to Boundary Layer Meteorology, 1999 – Roland B. Stull, Kluwer, Academic Publishers. 5. Environmental Chemistry, 2006- Anil Kumar Dey, New Age International publishers, West Bengal.	
Learning Outcomes	The knowledge they gain from the course will be an investment for their post-PG research as aerosol science/research is an emerging field.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 370 **Title of the Course: Aerosol and Climate Practical**
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Students undergoing course in any branch of Marine Sciences.	
Objective:	1. In the present course, trace metals and nutrients will be analysed from PM_{10} particulate matter collected from respirable dust sampler. 2. The main objective of this course is to study the atmospheric composition of aerosols. 3. These studies would help to understand the affect of rapid urbanisation and industrialisation on air quality.	
Content:	1. RDS sampler - principle and instrumentation (6 hrs; Ref: 1, 2, 3) 2. Method to collect dry deposited material by using PM 10 (6 hrs; Ref. 1, 2, 3) 3. Estimation of mass loadings of PM 10 (06 hrs; Ref: 1, 2, 3) 4. Estimation of water soluble metals (Fe, Zn, Cu and Pb) in dry deposited material (06 hrs; Ref: 4, 5, 6, 7) 5. Estimation of total metals (Fe, Zn, Cu and Pb) in dry deposited material(06 hrs; Ref: 4, 5, 6, 7)	24 hours
Pedagogy:	Demonstations/ Lab experiments.	

References/ Readings	1. Methods for air sampling and analysis (2nd edition), 1977 – Katz M, APHA Press Inc. 2. Methods of air sampling and analysis (3rd edition), 1989 - Lodge Jr., Lewis Publishers: Michigan. 3. Guidelines for the measurement of ambient air pollutant (Vol. 1), 2012 - NAAQMS series/36/2012-13. 4. Manual for geochemical analysis of marine sediments and suspended particulate matter, 1977 - Loring, D. H. and Rantala, R. T. T, Fish. Mar. Serv. Dev. Technical Report, 700. 5. Methods of Seawater analysis, 1983 - K. Grasshoff, M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim, 6. Analytical chemistry of seawater, 1975 - Riley, J.P., In Chemical Oceanography J.P. Riley and G. Skirrown (eds.), Vol. 3. Academic Press, London. 7. Standard methods for the examination of water and wastewater (20th edition), 1998 - APHA, Washington. D. C.	
Learning Outcomes	1. The main outcome of the study is to understand the quality of air through the analysis of dust, trace metal levels and nutrients in particulate (PM_{10}) and fine matter ($PM_{2.5}$). 2. The effect of different metals on the environment is studied based on their concentrations in the atmosphere. 3. These studies also would help for identification of hot spots near industrial or urban conglomerates. 4. Can be assessed through their possible sources and their implication on coastal waters of Goa. 5. Such studies along with crustal elements would be more informative about the sources and would suggest remedial measures to be adopted for their control.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 371 Title of the Course: Marine Microbial Ecology I
Number of Credits: 03
Effective from AY: June2018-19

Prerequisites for the course:	Students who have undergone courses of Semester I and II of Marine Sciences.	
Objective:	To provide basic information and concepts of marine microbiology and its importance. Further, also enables identification of microbes from the marine environments.	
Content:	Marine Microbiology its importance, existence and need; History of marine microbiology; Instruments and sampling methods; Modern methods; Microbial habitats and major types (producers, consumers, symbionts, probionts, etc.) in relation to their habitats; Evolution of sampling strategies and methods for assessment of microbial biodiversity . Characteristics of marine microbes; Distribution and abundance and their adaptations to pressure, depth, salt, temperature; Integrated effects of nutrient dynamics; Chemosynthesis and microbial heterotrophic metabolis ; Effect of ions of major and trace elements; Toxicity and mechanism of tolerance in marine microbes; Biochemical characterization of marine prokaryotes. Microbial role in cycling of N, P, S, and C; Concept of microbial loop in relation to marine food web dynamics ; Role of micro-organisms in DOM production and consumption;Microbial mineralization and oxidation of organic matter; Role of marine microbes in production of RDOC and sequestering of carbon dioxide; Pollution indictor and pathogenic marine microbes.	12 hours 12 hours 12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	

References/ Readings	1. Microbial Ecology of the oceans (2nd Edition), 2010 - Kirchman, D. L., John Wiley & Sons. 616 pages 2. Marine Microbiology (2nd Edition), 2011 - Munn, C. Garland Science. 320 pages 3. Marine Microbial Diversity: the key to Earths habitability, 2005 - Hunter – Cevera, J. Karl, D. and Buckley, M., American Academy of Microbiology. 4. Biological Oceanography, 2012 - Meller, C. B. and Wheeler P.A.. Wiley – Blackwell Publishers. 5. Marine Microbiology: Ecology and Applications (2nd edition), 2011 - Munn, C. Garland Science, Taylor and Francis group, NY. 6. Taxonomic scheme for the identification of marine bacteria, 1982 - Oliver, J. D., Deep Sea Research Part A., Oceanographic Research Papers, 29 (6); 795 – 798. 7. Marine Ecological Processes (2nd edition), 1995 - Valiella I., Springer – Verlag, New York.	
Learning Outcomes	Develop and provide information on the marine microbial ecology and enables applications of microbiology to understand ecological processes.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 372 Title of the Course: Marine Microbial Ecology II
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Students who have undergone courses of Semester I and II of Marine Sciences.	
Objective:	To provide basic information and concepts of marine microbiology and its importance. Further, also enables identification of microbes from the marine environments.	
Content:	Sampling strategies for molecular biological analysis; Meta-genomic analysis; Principles and applications of TFF for microbial molecular analysis; DNA/RNA extraction, principles and methods; Principles 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 weaver's index, simpson index, species richness, Chao, ACE indices and Leibshuff technique) for microbial biodiversity analysis.	12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/ Readings	1. Marine Microbial Diversity: the key to Earths habitability, 2005 - Hunter – Cevera, J. Karl, D. and Buckley, M., American Academy of Microbiology. 2. Ocean and Health: Pathogens in the marine Environment, 2005 - Belkin S. and Colwell, R. R.,Springer – Verlag, New York. 3. Marine Microbiology: Ecology and Applications (2nd edition), 2011 - Munn, C. Garland Science, Taylor and Francis group, NY. 4. Taxonomic scheme for the identification of marine bacteria, 1982 - Oliver, J. D., Deep Sea Research Part A., Oceanographic Research Papers, 29 (6); 795 – 798. 5. Marine Ecological Processes (2nd edition), 1995 - Valiella I., Springer – Verlag, New York.	
Learning Outcomes	Develop and provide information on the marine microbial ecology and enables applications of microbiology to understand ecological processes.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 373 Title of the Course: Marine Microbial Ecology Practical I
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Students who have undergone semester I and II of Marine Sciences.
Objective:	This course elucidates the basic concepts and techniques applied in the Marine Microbiology

Content:	1. Sterilization techniques, preparation of bacterial media, nutrient, broth & agar preparation of slants (6 hrs; Ref 1); 2. Method of sample collection (water) from marine environment (4 hrs; Ref 2), 3. Estimation of bacterial, fungal population and isolation (6 hrs; Ref 4) 4. Preservation of cultures, isolation of pure cultures microscopy: wet mounts (4 hrs; Ref 4), 5. Isolation of pathogenic organisms from water and sediments (4 hrs; Ref 5)	24 hours
Pedagogy:	Microbial laboratory techniques	
References/ Readings	1. Bergeys manual of systematic bacteriology (Vol. I), 1984 - (William & Willcens, Baltimore, MD, 518 pg 2. Marine and estuarine microbiology laboratory manual, 1975 – Rita R. Colwell – University Partk Press, 1975, 96 pgs. 3. Marine microbiology, a monograph & hydro-bacteriology, 1946 - C.E. Zobell, – Chronica botarica Compare, 240 pgs. 4. Laboratory methods in microbiology, 1966 - W.F. Harigan, M.E. Mc Cance, Academic press 1966, 362 pgs. 5. Manual of environmental microbiology, 1997 - G. J. Hurst , G. R. Knudsen, AsM Press, 894 pgs.	
Learning Outcomes	To acquaint with some of the basic methods/techniques to study the microbiology of marine environment.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 374 Title of the Course: Marine Microbial Ecology Practical II
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Students who have undergone semester I and II of Marine Sciences.	
Objective:	This course elucidates the basic concepts and techniques applied in the Marine Microbiology	
Content:	1. Identification of marine bacteria (4 hrs; Ref 3) 2. Separation of mixed culture, isolation, maintenance and preservation of pure culture (4 hrs; Ref 3) 3. Characterization, biochemical tests (4 hrs; Ref 1) 4. Staining of bacteria and cell morphology (4 hrs; Ref 1) 5. Marine microbes from different ecological niches (water column and sediments) with reference to physico-chemical conditions (8 hrs; Ref 5)	24 hours
Pedagogy:	Identification, isolation and staining of marine microbes	
References/ Readings	1. Bergeys manual of systematic bacteriology (Vol. I), 1984 - (William & Willcens, Baltimore, MD, 518 pg 2. Marine and estuarine microbiology laboratory manual, 1975 – Rita R. Colwell – University Partk Press, 1975, 96 pgs. 3. Marine microbiology, a monograph & hydro-bacteriology, 1946 - C.E. Zobell, – Chronica botarica Compare, 240 pgs. 4. Laboratory methods in microbiology, 1966 - W.F. Harigan, M.E. Mc Cance, Academic press 1966, 362 pgs. 5. Manual of environmental microbiology, 1997 - G. J. Hurst , G. R. Knudsen, AsM Press, 894 pgs.	
Learning Outcomes	To acquaint with some of the basic methods/techniques to study the microbiology of marine environment.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 375 **Title of the Course: Marine Geochemistry I**
Number of Credits: 02
Effective from AY: June2018-19

Prerequisites for the course:	Should have studied core courses of first and second semester of M.Sc. Marine Sciences along with respective practical. It is assumed that the students have basic knowledge of different branches of Marine Sciences and have ability to apply to understand the processes.	
Objective:	This course introduces concepts of Marine Geochemistry and help to understand processes associated with energy and material transfer from land to sea.	
Content:	Geochemical classification of elements - distribution and abundance of elements in lithosphere – Principle geochemical cycle, Chemical weathering. Suspended matter – Methods of collection and analysis, spatial and temporal variation of total suspended particulate matter in the ocean – Component composition and settling rates of suspended matter – Particle flux in the ocean and various techniques of measurement, Particulate organic matter in the sea: its origin, nature, composition and methods of measurements. Sedimentation – physicochemical factors in sedimentation – ionic potential, hydrogen ion concentration, redox potential and colloids – Behaviour of major and trace elements during sedimentation – Significance of organic content in sedimentation – Component composition and geochemistry of deep sea sediments – Application of major and minor elements in the reconstruction of marine paleo-environment.	12 hours 12 hours
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings	1. Introduction to geochemistry, 1967 Krauskopf, K. B., Mc.Graw-hill. 2. Geochemistry, 1962 Goldschmidt, V. M., Clarendon press. 3. Principles of geochemistry, 1956 Mason, B. and Moore, B., John Wiley & Sons, Inc. 4. Chemical oceanography (Vol. 1 & 3), 1975 Riley, J. P. and Skirrow, G., Academic Press, New York 5. Introduction to geochemistry, 1995 Krauskopf, K. B. and Bird, Mc-Graw Hill. 6. The geochemistry of natural waters, 1982 Drever, J. I.,Prentice-Hall, Inc., Englewood Cliffs, N.J. 7. Estuarine chemistry, 1976 Burton, J.D. and Liss, P. S., Academic Press. 8. Ocean chemistry and deep sea sediments, 1989 Open University Course Material. 9. Aquatic chemistry, 1996 Stumm, W. and Morgan, J.J., Wiley Interscience, New York. 10. Aquatic surface chemistry, 1987 Stumm, W., Wiley Interscience, New York. 11. Marine Chemistry, 1969 Home, R. A.,Reinhold Publishing Corporation, New York.	
Learning Outcomes	1. Understanding material transfer from land to sea through geochemical processes and geochemical processes within sediment column in the oceans.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 376 **Title of the Course: Marine Geochemistry II**
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Marine Geology and Marine Chemistry	
Objective:	1. To study the input of DOM from various sources into the Sea (atmosphere, rivers and marine sediments. 2. To understand the processes by which DOM is removed from sea water. 3. To study the complex formation of different metals with DOM in sea water.	
Content:	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.	12 hours
Pedagogy:	Lectures/ Tutorials/ assignments/self study.	

References/ Readings	1. Introduction to geochemistry, 1967 - Krauskopf, K.B., Mc.Graw-hill, Kogasuksha Ltd, International student edition. 2. Geochemistry, 1962 – Goldschmidt, V.M., Clarendon press. 3. Principles of geochemistry 1966 – Mason, B. 3rd edition published by John Wiley and Sons, Inc, New York. 4. Chemical oceanography (Vol. 1 & 3), 1975 – Riley, J.P. and Skirrow, G.(eds). Academic Press, New York. 5. Introduction to geochemistry, 1995 – Krauskopf, K.B. and Bird, Mc-Graw Hill, Kogasuksha Ltd, International student edition. 6. The geochemistry of natural waters, 1982 – Drever, J.I. 3rd Edition, Prentice Hall. 7. Estuarine chemistry, 1976 – Burton, J.D. and Liss, P.S., Academic Press, New York. 8. Ocean chemistry and deep sea sediments, 1989 – Open University Course Material. 9. Aquatic chemistry, 1996 – Stumm, W. and Morgan, J.J., Wiley - Interscience, New York. 10. Aquatic surface chemistry, 1987 – Stumm, W., Wiley – Interscience, New York. 11. Marine Chemistry, 1969 – Horne, R.A. Wiley - Interscience.	
Learning Outcomes	1. These studies would help to understand the rate at which DOM and removed from sea water by various processes. 2. These studies give an insight into how DOM can influence the state of inorganic compounds in sea water and 3. These studies would help in identification of organisms which use DOM as a source of an alternate food in the absence of essential nutrients.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 377 **Title of the Course: Marine Geochemistry III**
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Should have undergone the course Marine Chemistry (MSC 162).	
Objective:	This course develops concepts about the geochemistry of the marine environment that concerns chemistry of solid-solution interface and surface phenomena in aquatic systems.	
Content:	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.	12 hours
Pedagogy:	Lectures/ tutorials/ assignments/ self-study	
References/ Readings	1. Introduction to Geochemistry, 1967 - Krauskopf, K.B., Mc.Graw-hill. 2. Geochemistry, 1962 – Goldschmidt, V.M., Clarendon Press. 3. Principles of Geochemistry 1956 – Mason, B. and Moore, B., John Wiley. 4. Chemical Oceanography (Vol. 1 & 3), 1975 – Riley, J.P. and Skirrow, G., Academic Press. 5. Introduction to Geochemistry, 1995 – Krauskopf, K.B. and Bird, Mc-Graw Hill. 6. The Geochemistry of Natural Waters, 1982, 2002 – Drever, J.I., Prentice Hall. 7. Estuarine Chemistry, 1976 – Burton, J.D. and Liss, P.S., Academic Press. 8. Ocean Chemistry and Deep Sea Sediments, 1989, 1991 – Open University Course Material. 9. Aquatic Chemistry, 1996 – Stumm, W. and Morgan, J.J., Wiley- Interscience, New York. 10. Aquatic Surface Chemistry, 1987 – Stumm, W., Wiley – Interscience, New York. 11. Marine Chemistry, 1969 – Horne, R.A., Wiley Interscience. 12. Text Book of Physical Chemistry, 1981, Glasstone, S., Macmillan India Press. 13. Marine Chemistry and Geochemistry, 2010 – K.K.Turekian, Academic press.	
Learning Outcomes	1. Explain the importance of surface phenomena in the geochemistry of marine environment/aquatic systems. 2. Develop mathematical basis for adsorption isotherms applicable to trace metals in natural waters. 3. Explain the importance of the role played by colloids in trace metals cycling in marine environment/natural waters.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 378Title of the Course: Marine Geochemistry Practical I
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Should have undergone the course Marine Chemistry Practical I (MSC 166).	
Objective:	This course deals with the Analytical Chemistry of Seawater.	
Content:	1. Determination of dissolved organic N in seawater by alkaline - persulphate oxidation followed by spectrophotometric technique (6 hrs; Ref 1) 2. Determination of dissolved and particulate organic P in seawater by acid - persulphate oxidation followed by spectrophotometric technique (6 hrs; Ref 1) 3. Spectrophotometric determination of dissolved Fe in seawater by TPTZ – ascorbic acid method (6 hrs; Ref 1) 4. Spectrophotometric determination of dissolved Mn in seawater by formaldoxime method (6 hrs; Ref 1) 5. Spectrophotometric determination of dissolved B in seawater by curcumin method (6 hrs; Ref 1)	24 hours
Pedagogy:	Laboratory experiments/ field studies	
References/ Readings	1. Methods of Seawater Analysis, 1983, 1999 – Grasshoff, K., Ehrhardt, M. and Kremling, K.; Verlag Chemie, Weinheim, 419. 2. A Manual of Chemical and Biological Methods for Seawater Analysis, 1984 – Parsons, T. R., Maita, Y. and Lalli, C. M., Pergamon Press, Oxford.	
Learning Outcomes	1. Develop analytical skills to determine the concentrations of various chemical parameters, such as organic N, organic P, Fe, Mn and B in seawater/aqueous systems. 2. Apply techniques to seawater/natural waters to study the biogeochemistry of the marine environment/aquatic systems.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 379 Title of the Course: Marine Geochemistry Practical II
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Marine Geology and Marine Chemistry	
Objective:	1. The primary purpose of geochemistry is on one hand to determine quantitatively the composition of Earth and on the other hand to discover laws which control the distribution of individual elements. 2. The chemical analysis of sediment provides information about the concentration of different constituents. 3. The course work involves estimation of organic carbon and phosphorus and trace metals in sediments collected from different regions of marine environment.	
Content:	1. Determination of Organic carbon in sediment. (6 hrs; Ref 1) 2. Determination of phosphorus in sediment. (6 hrs; Ref 1, 2,3) 3. Sediment digestion procedure (8 hrs; Ref 1) 4. Estimation of Cr in sediment (5 hrs; Ref 4, 5) 5. Estimation of Zn in sediment (5 hrs; Ref 4, 5)	24 hours
Pedagogy:	Demonstrations/Laboratory experiments	

References/ Readings	1. Methods of Seawater Analysis, 1983, 1999 – Grasshoff, K., Ehrhardt, M. and Kremling, K.; Verlag Chemie, Weinheim, 419. **2.** A Manual of Chemical and Biological Methods for Seawater Analysis, 1984 – Parsons, T. R., Maita, Y. and Lalli, C. M., Pergamon Press, Oxford. 3. Manual for geochemical analysis of marine sediments and suspended particulate matter, 1992 - Loring, D. H. and Rantala, R. T. T., *Earth. Science. Rev*. 32: 235-283. 4. Chemical Analysis. In: Methods in plant Ecology, 1976 - Allen, S. E., Grimshaw, H. M., Parkinson, J. A., Quarmby, C. and Roberts, J.D. 1976., S. B. Chapman (eds.), Blackwell Scientific Publications, Oxford, Chapter 8, 411-466. 5. Methods of Seawater analysis, 1983 - Grasshoff, K.K. Grasskhoff, M. Ehrdardt and K. Krembling (eds.), Verlag Chemie, Weinneim, 419. 6. Analytical chemistry of seawater, 1975 - In Chemical Oceanography J.P. Riley and G. Skirrow (eds.), Vol. 3. Academic Press, London. 7. Standard methods for the examination of water and waste water analysis (22nd edition), 2012. Rice, E.W and Bridgewater L. American Public Health Association,Washington DC.	
Learning Outcomes	1. The analysis of organic carbon and phosphorus in sediment gives information about the nutrient status of sediment and its possible sediment composition. 2. The results of metal analyses in marine sediments would help in understanding the possible sources of these metals by considering local factors.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 380 Title of the Course: Marine Ecology
Number of Credits: 04
Effective from AY: June2018-19

Prerequisites for the course:	Students who have undergone courses of Semester I and II of Marine Sciences.	
Objective:	This course develops concepts in different aspects of marine ecology processes and ecosystem function associated with marine life.	
Content:	Marine ecosystems (pelagic and benthic ecosystem of open seas), Mangrove ecosystem species composition, distribution, adaptations, primary productivity, heterotrophic production, secondary communities and energy flow, Coral reef – formation, calcification, reef morphology, nutrition and symbiosis, Salt marsh ecosystem – species composition, distribution, nutrient dynamics, primary productivity and ecological processes and fate of salt marsh plant, Deep sea – sampling, constraints, adaptations. Marine food chains – role of DOM, POM, microbial loop, heterotrophic flagellates, bacteria, viruses in trophic transfer, microhabitats and recent concept of ecological efficiency, community structure diversity and ecosystem function, factor regulating community structure, Fish migrations and spawning. Ecology of harmful algal blooms – causative species, bloom formation and dynamics, propagation, decomposition and its impact on ecosystem function, behavioral adaptations, physical processes, cyst and dormant stages, shellfish poisoning and human health. Fouling communities – larvae and their adherence to substratum, mechanism, implications and control, Introduced species and marine bio-invasion – concept, alien species and effect on local ecosystem function, Benthic autotrophic production and metabolism.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	

References/ Readings	1. Marine Ecology: Processes, systems and impacts (2nd edition), 2011 - Kaiser, J.M., OUP Oxford. 501 pages. 2. Trait, R.V., 2013. Elements of Marine Ecology (3rd Edition), 2013 – Trait R. V., Elsevier. 366 pages 3. Marine biology: An ecological approach (6thed), 1988 – Nybbakken, J.W. and Bertness, M. D. Pearson/Benjamin Cummings 4. Biological Oceanographic Processes, 1984 – Parsons, T.R., Pregamon Press. 5. Marine Biological Processes (2nd ed), 1995 - Valiela, I., Springer Verlag Press. 6. Plankton and productivity in the oceans (Vol. 1 & 2), 1983 – Raymont, J.E.G., Pergamon Press. 7. Deep sea demersal fish and fisheries, 1997 – Merrett, N.R. Chapman and Hall, Springer 8. Reef fisheries, 1996 – Polunin, R.S.V. Springer Science & Business Media 9. Marine Ecological Processes, 1995 – Valiela Evans, Springer Verlag, New York, 686.	
Learning Outcomes	Explain the marine biological processes in different ecosystems including tropical and polar waters. Also addresses marine ecological issue like HAB, sediment communities and processes related to these ecosystems.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 381Title of the Course: Marine Ecology Practical
Number of Credits: 02
Effective from AY: June2018-19

Prerequisites for the course:	Students who have undergone courses of Semester I and II of Marine Sciences.	
Objective:	This course focuses on the methods of estimating water quality parameters and the use of different techniques to address various issues in Marine Ecology.	
Content:	**Module – I** 1. Estimation of primary production by using light and dark bottle method (6hrs; Ref 7) 2. Estimation of chlorophyll and phaeo-pigments in seawater sample using a spectro-photometric method (6hrs; Ref 14) 3. Quantitative estimation of phytoplankton using stereoscopic microscope and an analysis of sea water sample for phytoplankton cell count (6hrs; Ref 19) 4. Qualitative estimation of zooplankton using stereoscopic microscope and an analysis of sea water sample for zooplankton count (6hrs; Ref 6) **Module – II** 1. Quantitative estimation of zooplankton using volume displacement, wet weight and dry weight method (3hrs; Ref 6) 2. Preparation of permanent slides of few phytoplankton and zooplankton using DPX (6hrs, Ref 8) 3. Designing of an experimental set-up to study uptake of oxygen by fish in the laboratory (9hrs; Ref 12) 4. Computation of species diversity (H', J and D) indices using the data of phytoplankton and zooplankton analysis and their implications in ecological studies (6hrs; Ref 2)	24 hours 24 hours
Pedagogy:	Laboratory techniques, designing of experiments, computations and data interpretations	

References/ Readings	1. A Manual of Chemical and Biological Methods for Seawater Analysis, 1984 - Parsons T.R., Maita T. & Lalli C.M., Oxford and New York: Pergamon Press, 184pp. 2. Population ecology. A unified study of plants and animals, (3rdEdition), 1996 - Begon M., Mortimer M. & Thompson D.J., Blackwell Science Ltd. 247 pp. 3. Zooplankton Methodology, collection and identification – A field manual, 2004 - Goswami S.C., National Institute of Oceanography, 16 pp. 4. Stomach content analyses - A review of methods and their application, 1980 - Hyslop E.J. (1980), Journal of Fish Biology, **17**:411 – 429. 5. Perspectives in Ecological Theory, 1968 - Margalef R.Chicago: University of Chicago Press, 111 p. 6. Ecological Methodology (2nd ed.), 1999 - Krebs C.J., Benjamin Cummings, 624 pp. 7. Plankton and productivity in the oceans (Vol. 1 & 2), 1983 – Raymont, J.E.G., Pergamon Press. 8. A Simple Method for the Preparation of Permanent Slides from Cell Cultures, Stain Technology (2009), Volume 59, 1984 - Issue 6 by Lina Wasserman &Gania Kessler-Icekson, Pages 353-354.	
Learning Outcomes	Ecological methods for evaluation of water quality and assessment of productivity. Also guides to formulate and design the experimental setup to provide insight in the specific issues.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 382Title of the Course: Sedimentology
Number of Credits: 04
Effective from AY: June2018-19

Prerequisites for the course:	Fundamental courses in all the branches of Marine Sciences of this University or any other University recognized as equivalent.	
Objective:	This course introduces sediment types and their distribution, concept of facies, heavy mineral zones, sedimentary depositional environments, sedimentary rocks and diagenesis.	
Content:	Distribution and genesis of terrigenous, biogenous, chemogenous, volcanogenic, authigenic and extra terrestrial (cosmogenous) sediments in the world ocean – Rate of sedimentation in the oceans. 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, heavy mineral zones - X ray diffraction technique and its use in mineral and sediment study. Sedimentary depositional environments – Aeolian, laccustrine, glacial desert, fluvial, coastal shallow marine and deep sea – Sedimentary and faunal markers of paleoenvironmental conditions. Sedimentary rocks – Classification, properties, origin and importance – Sandstone, limestone, mudstones and evaporites – Sedimentary structures formed by unidirectional water flows, water waves, airflows, liquefaction and current drag, diapirism and differential loading, desiccation and shrinkage structure – Diagenesis: general considerations, terrigenous clastic sediments, carbonate sediments, evaporates and hydrocarbons, Diagenesis of silica, iron and Manganese.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	Lectures / Assignments / Seminars / Discussion	

References/ Readings	1. Sedimentation in the world ocean, 1972 lisitzin, A. P., Soc. Of E. C. Paleontologists. 2. Sedimentology, 1982 Leeder, M. R., George Allen & Unwin. 3. Sedimentary rocks (3rd edn.), 1984 Pettijohn, E. J., C.B.S. Publ. and Distrib. 4. Stratigraphy and sedimentation, 1963 Krumbein, W. C. and Sloss, L. L., W. H. Freeman & Co. 5. Sedimentary environments and facies (2nd edn), 1986 Reading, H.G., Blackwell Sci Publ. 6. Depositional sedimentary environments, 1986 Reineck, H.E. and Singh, I.B., Springer Verlag. 7. Origin of sedimentary rocks, 1972 Blatt, H., Middleton, G. and Englewood, M.R., Cliff, New Jersey. 8. Principles of sedimentology, 1978 Friedman, G.M. and Sanders, J. E., John Wiley & Sons. 9. Procedures in sedimentary petrology, 1971 Carver, R.F., Wiley Interscience. 10. Sedimentary structures: their character and physical basis (Vol.1 & 2), 1982 Allen, J.R.I., Elsevier. 11. Physical processes of sedimentation: An introduction, 1970 Allen, J.R., George Allen & Unwin. 12. Ancient sedimentary environments: A brief survey, 1970 Selley, R. C., Chapman & Hall. 13. Atlas and glossary of primary sedimentary structures, 1964 Pettijohn, F. J. and Potter, P. E., springer verlag. 14. Sand and sandstone, 1972 Pettijohn, F. J., Potter, P.E. and Siever, R., Springer Verlag.	
Learning Outcomes	1. Understanding sediment processes, paleo-environments, formation. 2. Ability to reconstruct paleo-climate and paleo-environments	

Programme: M. Sc. (Marine Sciences)
Course Code: MSO 383Title of the Course: Sedimentology Practical
Number of Credits: 02
Effective from AY: June2018-19

Prerequisites for the course:	Fundamental courses in all the branches of Marine Sciences of this University or any other University recognized as equivalent.	
Objective:	This course introduces to experiments to analysis to understand depositional environments and processes.	
Content:	**Module – I** 1. Grain size analysis – sand, silt, clay using pipette method – estimation and interpretation – at least ten samples from a sediment core (12 hrs; Ref 1,5) 2. Determination of organic carbon – at least ten samples from a sediment core (4 hrs; Ref 1, 4,6) 3. Heavy mineral identification (4 hrs; Ref 1,2) 4. Study of stratigraphic correlation (4 hrs; Ref5) 5. Study of paleo-current analysis (8 hrs; Ref4)	24 hours
	Module – II 1. Measurement of sphricity and roundness of sediment grains - at least 30 grains (8 hrs; Ref 1,2) 2. Identification of sedimentary rocks (4 hrs; Ref 3,7) 3. Identification of sedimentary structures (4 hrs; Ref 3,4) 4. Study of sedimentary facies (4 hrs; Ref 4,5) 5. Preparation of samples for X-ray diffraction analysis (4 hrs; Ref 4,6) 6. XRD analysis for clay minerals (4 hrs; Ref 4,6) 7. Clay mineral identification and estimation of Semiquantitative percentages and interpretation (4 hrs; Ref 4,6)	24 hours
Pedagogy:	Laboratory experiments / Computations / Plotting and Interpretations and analysis	

References/ Readings	1. Exercises in sedimentology, 1982 Freidman, G. M. and Johnson K. G., John wiley& sons. 2. A practical approach to sedimentology, 1987 Londholm, R., CBS Publication and Distributors. 3. Practical manual of sedimentary petrology, 1987 Babu S. K. and Sinha, D. K., CBS Publication and Distributors. 4. Procedures in sedimentary petrology, 1971 Carver, R. F., Wiley Interscience. 5. Text book of sedimentary petrology, 1981 Varma, V. K. and Prasad, C., Intl. Book Distribution. 6. Scientific method of analysis of sediments, 1987 Griffiths, J. C., McGraw – Hill. 7. The study of rocks in thin sections, 1985 Moorhouse, W. W., CBS Publication and Distributors. 8. Rutley's elements of mineralogy, 1984 Read, H. H., CBS Publication and Distributors.	
Learning Outcomes	1. Conducting laboratory experiments. 2. Analysis of data to understand paleo-current direction, facies, stratigraphic correlation, sedimentary structure, depositional environments. 3. Ability to interpret data sets to understand processes.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 461 Title of the Course: Estuarine and Coastal Physical Oceanography
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Students undergoing course in any branch of Marine Sciences.	
Objective:	The course is introduced to impart knowledge about the hydrodynamics of inland and coastal waters. Such a knowhow is imperative to design any activity related to environmental impact assessment.	
Content:	Sea level set up and buoyancy driven flows. 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 theorem, tidal analysis and prediction – salinity intrusion – gravity driven freshwater flow – estuarine circulation and mixing – stratification and entrainment – Salt – balance technique , Conservative pollutants, non - conservative pollutants, coupled non-conservative pollutants, Fronts in estuaries.	12 hours
Pedagogy:	The course is taught as a theory and many case studies are given to present as class seminar. This is to get an idea about the numerous problems confronting the coastal waters both due to anthropogenic and natural processes.	
References/ Readings	1. Physical processes in Estuaries, 1988 – John Dronkers and Wim Van Leussen, Springer Verlag. 2. Physical Oceanography, Vol 2, 1960 – A. Defant., Pergamon press. 3. Waves, Tidal and Shallow water processes, 1989 – The Open University, Walton Hill, Pergamon press. 4. Coastal oceanography, 1982 – H. G. Gade, A Edward and H. Svendson, plenum press. 5. Estuaries – a physical introduction (2nd edition), 1997 – K. R. Dyer, John Wiley and sons. 6. Regional Oceanography – an Introduction (2nd edition), 2003 – Daya publishing house – New Delhi.	
Learning Outcomes	This would equip the students to plan and execute any studies related to coastal and estuarine ecosystem.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 462 Title of the Course: Estuarine Chemistry
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Should have undergone the course Marine Chemistry (MSC 162).	
Objective:	This course develops concepts about the chemistry of the estuarine environment that concerns the study of the properties and interactions of the substances present in the estuarine environment.	
Content:	Salinity distribution in estuaries – a chemical perspective, 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, pH and major elements in estuarine water.	12 hours

Pedagogy:	Lectures/tutorials/assignments/self-study.	
References/ Readings	1. Estuarine Chemistry, 1976 - Burton, J.D. and Liss, P.S., Academic Press. 2. Practical Estuarine Chemistry, 1985 – Head, P.C., Cambridge University Press. 3. Chemistry and Biogeochemistry of Estuaries, 1980 – Olausson, E. and Cato, I., John Wiley & Sons. 4. Chemical Oceanography (Vol.7), 1978, Riley, J.P. and Chester, R., Academic Press. 5. Waves, Tides and Shallow-Water Processes, 1991, 2005 – The Open University. 6. Coastal and Estuarine Sediment Dynamics, 1986 – Dyer, K.R., Wiley. 7. Estuarine Hydrography and Sedimentation, 1980 – Dyer, K.R., Cambridge University Press. 8. Biogeochemistry of Marine Dissolved Organic Matter, 2002–D.A.Hansell and C. A. Carlson., Academic Press. 9. Biogeochemistry of Estuaries, 2007 – Thomas S. Bianchi, Oxford University Press. 10. Treatise on Estuarine and Coastal Science - Vol. 4: Geochemistry of Estuaries and Coasts, Vol. 5: Biogeochemistry, 2012, E. Wolanski and D. McClusky, Elsevier Inc.	
Learning Outcomes	1. Provide a comprehensive understanding of the properties and interactions of the substances present in the estuarine environment. 2. Explain the key processes operating in the estuarine environment. 3. Explain the importance of dissolved O_2, pH and the CO_2 problem. 4. Explain the biogeochemical cycling of major seawater constituents from the perspective of the global biogeochemical cycling of elements.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 463 Title of the Course: Estuarine Biology
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Marine Biology and Marine Ecology	
Objective:	This course develops concepts pertaining to carbon dioxide cycle in the estuarine and coastal environment and elucidate role of anthropogenic inputs on the carbon cycle.	
Content:	Primary productivity in coastal and estuarine waters, Oceanic carbon cycle, production and transformation of organic matter, external and internal sources of carbon, Dissolved Organic Matter – sources, aerobic and anaerobic environments, losses, decomposition, labile and refractory phase, fermentation, nitrate and sulfate reduction, methanogenesis, DOM as biological activity.	12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/ Readings	1. Estuarine Ecology. 2nd Edition. – K. R. Dyer, John Wiley and Sons. 568 pages. 2. The Biology of Estuarine Management. Wilson, J. 2012. Springer science and business media. 204 pages 3. Elements of Marine ecology (4thEdition), 1982 – Tait, R.V. and Dipper, F. Butterworth-Heinemann. 4. An introduction to Marine Sciences, 1988 – Meadows, P.S. and Campbell, J.J. John Wiley and Sons. 5. Textbook of Marine Ecology, 1989 – Nair, N.B. and Thampy, D.M. Macmillan 6. Advances in marine biology, Vol. 20, 1982 - Academic Press Ltd. New York. 7. Advances in marine biology, Vol. 36, 1999 – Press, New York 8. Marine Biology – An ecological approach 6th ed), 2005 – Nybbakken, J. W and Bertness, M. D. Pearson/Benjamin Cummings	
Learning Outcomes	Processes related to the carbon cycle and productivity in the marine environment	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 464 Title of the Course: Estuarine and Coastal Geology
Number of Credits: 01
Effective from AY: June2018-19

Prerequisites for the course:	Fundamental courses in all the branches of Marine Sciences of this University or any other University recognized as equivalent and courses defined in semester III.	
Objective:	This course introduces estuarine and coastal Geology with respect to sub-divisions, morphological units and processes including sediment distribution and depositional environments.	
Content:	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. 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.	12 hours
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings	1. Estuarine chemistry, 1976 Burton, J. D. and Liss, P. S., Academic Press, New York and London. 2. Practical estuarine chemistry, 1985 Head, P. C., Cambridge: Cambridge University Press Wiley Chichester. 3. Chemical oceanography (Vol.7), 1978 Riley, J. P. and Chester, R., Academ- ic Press, London. 4. Waves, tides and shallow-water processes, 1991 The Open University. 5. Coastal and estuarine sediment dynamics, 1986 Dyer, K. R., John Wiley & Sons. 6. Estuarine hydrography and sedimentation, 1986 Dyer, K. R., John Wiley & Sons. 7. Beach processes and sedimentation, 1976 Komar, P. D., Prentice Hall. 8. Sea-level rise and coastal subsidence: causes, consequences and strategies, 1966 Milliman, J.D. and Haq, B. U.,Kluwer Academic. 9. Introduction to geochemistry, 1967 Krauskopf, K. B., McGraw-Hill. 10. Elements of ecology (3rd edition), 1982 Tait, R. V., Springer. 11. An introduction to Marine Sciences, 1988 Meadows, P. S. and Campbell, J. J., Campbell BSc, FRES. 12. Textbook of Marine Ecology, 1989 Nair, N. B. and Thampy, D. M.The Open Universit Butterworth.	
Learning Outcomes	1. Understanding Geology of estuarine and coastal sedimentary environments, processes and evolution. 2. Ability to understand and reconstruct estuarine and coastal environments	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 465 Title of the Course: Dynamic Oceanography – I
Number of Credits: 02
Effective from AY: June2018-19

Prerequisites for the course:	Physical Oceanography, Geophysical Fluid Dynamics and Ocean Atmosphere Coupling and Climate courses.	
Objective:	To understand the laws that govern ocean motion and formulate the laws that describes this motion.	
Content:	Basic physical laws used in oceanography – Classification of forces and motion – Equation of continuity – static stability – double diffusion – Equation for the mean or average motion – Non-linear terms in the equation of motion – Eddy viscosity.	12 hours
	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.	12 hours
Pedagogy:	Lectures/Tutorials/ assignments	

References/ Readings	1. Introductory Dynamical Oceanography, 1983 – Pond, S and Pickard, G.H., Pergamon Press, U.K. 2. Principles of Physical Oceanography, 1966 – Newman, G. and Pierson, W.J., PrenticeHall, Inc., New Jersey, U.S.A. 3. Physical Oceanography (Vol.1) 1961 – Defant, A., Oxford pergamon press, U.K. 4. The dynamics of the upper ocean (2nd edition) 1977 – Phillips, O.M., Cambridge Univ. Press, U.K. 5. Modeling and prediction of the upper layers of the ocean, 1977 – Krous, E.B. (Ed.). 6. Modeling of marine systems, 1986 – Nihoul, J.C.J., Elsevier Scientific Publ. Co., Oxford, U.K. 7. Atmosphere – ocean Dynamics, 1982 - Gill, Adrian E, International Geophysics, 30 Academic press, New York.	
Learning Outcomes	Formulate equations that describe the ocean motion, explain the motion resulting at molecular level,explain types of vorticity and its role in ocean circulation.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 466 Title of the Course: Dynamic Oceanography – II
Number of Credits: 02
Effective from AY: June2018-19

Prerequisites for the course:	Students undergoing course in any branch of Marine Sciences.	
Objective:	This course is introduced to train the students in the application of various aspects of Physics and those learned under geophysical fluid dynamics in the III semester to Ocean dynamics. One of the country's requirements in the field of ocean and atmospheric research is numerical modelers, who model various dynamics of different time scales. Especially when the country's economy is agrarian for which monsoon is in important ingredient. Hence fundamentals of numerical modeling too are included in the syllabus.	
Content:	Currents with friction – The equation of motion with friction: Transport and upwelling – Bottom friction and shallow water effects – Ekman's solution to the equations of motion with friction .Limitation to Ekman's theory – Sverdrup's solution for the wind driven circulation – Stommel's contribution – The planetary wind field, upwelling and sinking with special reference to the Indian ocean — Westward intensification – equatorial current system – Munks equation - Boundary layer approach to obtain a solution to Munk's equation – The mixed layer of the ocean. Co-ordinate system – Governing equations – Boundary conditions layer averaged equations – Staggered grid systems – Finite difference method- Model spin up time-Model stability condition.	12 hours 12 hours
Pedagogy:	Though the course is taught in class room, a significant component of ocean dynamics (especially important publications) used to be presented in student's seminar.	
References/ Readings	1. Introductory Dynamical Oceanography, 1983 – Pond, S and Pickard, G.H., Pergamon Press, U.K. 2. Principles of Physical Oceanography, 1966 – Newman, G. and Pierson, W.J., Prentice Hall, Inc., New Jersey, U.S.A. 3. Physical oceanography (Vol.1) 1961 – Defant, A., Oxford Pergamon press, U.K. 4. The dynamics of the upper ocean (2nd edition) 1977 – Phillips, O.M., Cambridge Univ. Press, U.K. 5. Modeling and prediction of the upper layers of the ocean, 1977 – Krous, E.B. (Ed.), Pergamon press 6. Modeling of marine systems, 1986 – Nihoul, J.C.J., Elsevier Scientific Publ.Co. Oxford, U.K. 7. Atmosphere – Ocean Dynamics, 1982 - Gill, Adrian E, International Geophysics, 30 Academic press, New York.	
Learning Outcomes	Trained manpower in the field of Ocean dynamics with good Knowledge in the modeling aspect.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 467 Title of the Course: Physical and Inorganic Chemistry of Seawater
Number of Credits: 04
Effective from AY: June2018-19

Prerequisites for the course:	Should have undergone the course Marine Chemistry (MSC 162).	
Objective:	This course develops concepts in understanding the detailed nature of the structure and physical chemistry of liquid water and aqueous electrolytic solutions that are central to marine chemistry. Also, this course develops a theoretical basis of chemical reactions and processes – acid-base reactions, oxidation-reduction reactions, complex formation, and precipitation and dissolution reactions – that occur in natural waters.	
Content:	The structure of liquid water – Theories of water structure, colligative properties of seawater with the thermodynamic derivations of expressions for boiling point elevation and freezing point depression, electrostriction – The Thermodynamics of seawater – Ideal and real solutions. Equation of state for pure water and seawater, thermodynamics of PVT changes in seawater, activities, activity coefficients; Debye - Huckel theory and the Debye - Huckel limiting law; heats of solution, dilution, and mixing. Acids and bases – basic concepts, proton condition and the electroneutrality of solutions; pH as a master variable – log C – pH diagram for monoprotic and diprotic acid – base system; buffer pH, buffer intensity – Oxidation and Reduction Reactions – Redox equilibria, electron activity and pE – Peters-Nernst equation; pE-pH diagram for the aqueous chlorine system, pE – pc diagram for Fe (II) - Fe (III) system, Kinetics of redox processes (Oxidation of Fe (II) and Mn (II) only). Metal Ions in Aqueous solutions – hydrolysis of metal ions, formulation of stability constants, the stability of hydrolysis species, chelates and the chelate effect; Precipitation and dissolution – Heterogeneous equilibria, solubility product and saturation; the solubility of oxides and hydroxides – carbonate system closed to atmosphere and in equilibrium with CO2(g); the stability of hydroxides and carbonates; crystal formation – The initiation and production of the solid phase – Solubility of silicates, gibbsite and iron (oxy) hydroxides.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	Lectures/ tutorials/ assignments/ self-study	
References/ Readings	1. Marine Chemistry, 1969 – Horne, R.A., Wiley – Interscience, London. 2. Aquatic Chemistry, 1981, 1996 – Stumm, W. and Morgan, J.J., Wiley-Interscience, New York. 3. Water Chemistry, 1980 – Snoeyink, V.L. and Jenkins, D., John Wiley & Sons, New York. 4. Principles of Aquatic Chemistry, 1983 – Moral, E.M.M., Wiley Interscience 5. Chemical Kinetics and Process Dynamics in Aquatic Systems, 1994 – Brezonik, P.L., Lewis Publ., London. 6. Aquatic Chemistry, 1995 – Huang, C.P., O'Melia, C.R. and Morgan, J.J. American Chemical Society, Washington, DC. 7. Aquatic Surface Chemistry, 1987 – Stumm, W., Wiley Interscience, New York. 8. Chemical Oceanography (vol. 1), 1975 – Riley, J.P. and Chester R., Academic Press. 9. Text Book of Physical Chemistry, 1981 - Glasstone, S., Macmillan Indian Press. 10. The Geochemistry of Natural Waters, 1982, 2002 - Drever, J.I., Prentice Hall. 11. Introduction to Geochemistry, 1995 – Krauskopf, K.B. and Bird, Mc.Graw Hill. 12. Water Chemistry – An Introduction to the Chemistry of Natural and Engineered Aquatic Systems, 2011 – P. L. Brezonik and W. A. Arnold, Oxford University Press.	
Learning Outcomes	1. Provide a comprehensive understanding of the seawater as an aqueous electrolytic solution. 2. Illustrate numerical applications of PVT relationships for seawater and the changes in thermodynamic properties of seawater. 3. Explain the key reactions and processes occurring in aquatic environment. 4. Apply the general concepts to aquatic systems of interest such as ocean waters, estuaries, rivers, lakes, ground waters, and soil water systems, as well as in water technology.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 468Title of the Course: Marine Biodiversity, Conservation and practices
Number of Credits: 04
Effective from AY: June2018-19

Prerequisites for the course:	Marine Biology and Marine Ecology	
Objective:	Addresses basic concepts of biodiversity, Intellectual Property Right, values and its implications on the environment and human life with regard to the global warming and climate change.	
Content:	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. 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. Biodiversity and Intellectual Property Rights (IPR) and bio-piracy, life patenting and implications, impact of GATT on farmer's right, indigenous, traditional knowledge and IPR, biodiversity conservation and IPR, Bio-invasion, Indian fisheries and responsible shrimp farming, fishing through the food webs. 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.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	lectures/ tutorials/assignments/self-study	
References/ Readings	1. Marine Biodiversity Conservation: A practical approach, 2014 - Hiscock, K. Routledge. 318 pages 2. Marine Biodiversity: Patterns, processes, assessment, threats, management conservation, 2007 - Queiroga, H., Cunha, M.R., Cunha, A., Moreira, Q. V., Rodrigues, A. M., Serodio, J., Warwick, R. M., Springer science and business media. 353 pages. 3. Marine Biodiversity - Pattern and Processes, 1997 - Rupert F.G. Ormond, John.D.Gage and Martin.V. Angel (eds.), Cambridge University press: 449pp. 4. Biodiversity and Environment, 2004 - Arvind Kumar, S. B. Nangia, A.P.H. Publication Corporation, New Delhi, 659 pp. 5. Biodiversity Conservation, 1994 - Vandana Shiva (eds.), Publication of Indian National Trust for Art and Cultural Heritage, New Delhi, 315 pp.	
Learning Outcomes	Provides a holistic view of the Marine Biodiversity with emphasis on Intellectual Property Right and conservation policies and laws.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSC 469 Title of the Course: Tectonics, Geophysics and Structural Geology
Number of Credits: 04
Effective from AY: June2018-19

Prerequisites for the course:	Fundamental courses in all the branches of Marine Sciences of this University or any other University recognized as equivalent and courses defined in semester III
Objective:	This course introduces tectonics – Earthquakes, Volcanoes, Mountain chains, geophysical methods – Gravity, Magnetic and Seismic, and Structural Geology with respect to concepts and applications in Earth processes.

Content:	Earth Quakes - classification, magnitude, epi-centre, recoding - seismographs, shadow zone, important earth quakes, causes. Volcanoes - magma, lava, volcanic land forms, famous eruptions. Mountains and mountain chains 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, echosounder, side scan sonar and sparker. Hydrography – position fixing, depth measurement and sea bed mapping technique, hydrographic chart. Computation, plotting and interpretation of gravity variations, identification of anomalies and interpretation of the data set. Computation of depth of ore body using half anomaly method. Apply gravity corrections and observations. Computation, plotting and interpretation of magnetic variations, 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 variations to understand depth of horizontal sedimentary bed using both reflection and refraction methods. Study of seismic profiles, sections and interpretation of features. Integrated interpretation of geophysical data, Application of geophysical methods in offshore exploration for oil natural gas and other minerals. Structural Geology - Folds - parts of fold, nomenclature, types, causes; Faults - nomenclature, types; Joints. Minerals and their physical properties, Rocks - classification and properties. Ground water and saline water intrusion on the coastal plain and ground water.	12 hours 12 hours 12 hours 12 hours
Pedagogy:	Lectures / Assignments / Seminars / Discussion	
References/ Readings	1. Introductory oceanography (5thed), 1988 Thurman, H.V., Columbus Mercill Publ. Co, Ohio. 2. Oceanography (5thed), 1990 Grant Gross, M., Englewood Cliffs, N.J. Prentice Hall. 3. Marine Geology and Oceanography of the Arabian Sea and coastal Pakistan, 1984 Haq. B. U. and Milliman, J. D., Van Norstrand Reinhold Co. 4. Marine Geology, 1982 James P. Kennet, Prentice Hall INC Englewood, Cliffs, N. J. 07632. 5. Earth Science, 1985-Mamowitz and Spaulding,Heath and Company, Heath. 6. Principles of Geophysical Prospecting, 1976 Dobrin, M. B., Mc.Graw Hill. 7. Geophysical Prospecting for Oil, 1976 Nettleton, L. L., McGraw Hill. 8. Exploration Seismology (Vol. 1 and 2) 1982, 1983 Sheriff, R. E. and Geldant, L. P., Cambridge Univ. Press, U.K.36 9. Developments in Solid Earth Geophysics (Vol.5) Spectral analysis in geophysics, 1974 Bath Markens. 10. Seismic Prospecting Instruments (Vol.1) 1972 Evenden, B. S., Stone, D. R. and Anstey, Gebrudev Borntraege,*Berlin.* 11. Structural Geology, 1972 M.P. Billings, Third Edition,Prentice Hall College Div.	
Learning Outcomes	1. Understanding tectonics, geophysical methods and structural geology – their concepts and application in understanding earth processes. 2. Ability to use concepts to understand earth processes and reconstruct tectonics and paleoenvironments.	

Programme: M. Sc. (Marine Sciences)
Course Code: MSD 480Title of the Course: Dissertation
Number of Credits: 08
Effective from AY: June, 2018-19

Prerequisites for the course:	Students who have undergone semester I and II of Marine Sciences.	
Objective:	This course facilitates undertaking of project work based on the knowledge acquired in the subject, thereby developing an aptitude for research to address specific problems in Marine Sciences.	
Content:	Project work based on the interest of the student and the expertise and facilities available in the Department.	192 hours
Pedagogy:	Discussions/literature collection/design/field trip/analysis and interpretations.	
References/ Readings	The candidate will carry out a detailed review of literature related to the project work assigned by the concerned teacher.	

Learning Outcomes	Ability to design and undertake scientific suveys, plan and execute the objectives of the project work. To develop an analytical mind to elucidate the existing lacunae in the area and to undertake research and to inculcate the art of scientific writing.	

Head

Marine Science