UNIVERSITY OF CALCUTTA

Notification No. CSR/ 73 /18

It is notified for information of all concerned that the Syndicate in its meeting held on 13.07.2018 (vide Item No.11) approved the Syllabus of Two-Year (Four-Semester) M.Sc. Course of Study in Marine Science under CBCS in the Post-Graduate Departments of the University and in the affiliated Colleges offering Post-Graduate Courses under this University, as laid down in the accompanying pamphlet.

The above shall be effective from the academic session 2018-2019.

SENATE HOUSE
KOLKATA-700073
The 17th August, 2018

(Debabrata Manna)
Deputy Registrar (Acting)

UNIVERSITY OF CALCUTTA

M.Sc. Marine Science Course Structure & Syllabus Semester System

Effective from Academic Session 2016-17

Course Code	Theoretical / Practical	Topics /Subjects	Marks	Credit
		I SEMESTER		
MST101	Theoretical	Introductory Physical Oceanography	**50**	**4**
MST102	Theoretical	Fundamentals of Chemical Oceanography	**50**	**4**
MST103	Theoretical	Fundamentals of Marine Geology	**50**	**4**
MST104	Theoretical	Basics of Biological Oceanography	**50**	**4**
MSP105	Practical	Biological & Geological Oceanography	**50**	**4**
		Total	**250**	**20**
		II SEMESTER		
MST201	Theoretical	Marine Meteorology& Dynamic Oceanography	**50**	**4**
MST202	Theoretical	Marine and estuarine chemistry	**50**	**4**
MST203	Theoretical	Marine Geology	**50**	**4**
MST204	Theoretical	Marine Ecology & Marine Pollution	**50**	**4**
MSP205	Practical	Physical & Chemical Oceanography	**50**	**4**
		Total	**250**	**20**
		III SEMESTER		
MST301	Theoretical	Coastal Geomorphology and Coastal Zone Management	**50**	**4**
MST302	Theoretical	Marine Microbiology and Brackish Water Fisheries management	**50**	**4**
MSP303	Practical	Marine Microbiology and Brackish Water Fisheries management	**50**	**4**
MSCB304	Theoretical	Choice base credit system course A other than Marine Sc	**50**	**4**
MSCB305	Theoretical	Choice base credit system course B other than Marine Sc	**50**	**4**
		Total	**250**	**20**
		IV SEMESTER		
MST401	Theoretical	Modelling &Computational Methods in Oceanography	**50**	**4**
MSP 402	Practical	Modeling & Computational Methods & in Oceanography	**25**	**2**
MST403	Theoretical	Special Paper (Any One) (i) Physical Oceanography (ii) Chemical Oceanography (iii) Biological Oceanography (iv) Geological Oceanography	**100**	**8**
MSD404	Dissertation	Dissertation / Review / Field work Project Submission & Seminar Presentation and Grand Viva Voce	**75**	**6**
		Total	**250**	**20**
		Grand Total (Semester I + II + III + IV)	**1000**	**80**

MST101: INTRODUCTORY PHYSICAL OCEANOGRAPHY

Basics approaches in Physical oceanography in marine systems: Physical laws of ocean; chaos complexity & bifurcations, non-linear systems, energy paradigms: (a) ocean energy & (b) tidal energy, wave propagation in shallow water, gravity waves; Stokes' Law and its application in marine organisms.

Tides: types of tides and tide generating forces; tidal theories- equilibrium & dynamic theories; tides and tidal currents in shallow seas, estuaries and rivers.

Ocean waves: types of ocean waves; wind generated waves in the oceans and their characteristics; shallow and deep water waves; propagation, refraction, and reflection of waves; wave spectrum and principles of wave forecasting; wave induced near shore current, Long shore current, reap current and sediment movement, storm wave and sediment transport.

Applications of basic Mathematics to Oceanography:
Complex Number –De-Moivre's Theorem and its applications, Definition of inverse circular and hyperbolic functions,
Matrix –Application of Eigen Values and Eigen Vectors to oceanography,
Application of differentiation – Velocity, acceleration, related rates,
Application of integration to growth and decay problems, Centre of gravity, moment of inertia, Problems related to oceanography,
Differential equation **–** First and second order linear equations, Simultaneous differential equations,
Partial Differentiation; Partial Differential Equation **–** Wave equation, Heat Equation

MST102: FUNDAMENTALS OF CHEMICAL OCEANOGRAPHY

Composition and stoichiometry of seawater: Constancy of composition for seawater; Chlorinity& the concept of salinity and the methods of their determination; cclassification of elements present in seawater; mmajor, minor and trace elements their behaviour, distribution and biological interactions; variations of Isotopic composition of seawater; radionuclides in the sea; abundance of stale isotopes in marine environment.Acidification of ocean and concept of blue carbon.

Seawater and ocean characteristics: physical Properties of seawater; typical distribution of water characteristics in the oceans, major water masses of the world's oceans and their characteristics; T-S diagram.

Mass balance in the Ocean: Steady state Ocean; global element cycle; geochemical balances of elements and the concept of residence time; Mass balance and two box model for oceans; cchemical exchanges across interfaces; residence times of elements in seawater.Water cycle.

Origin of seawater: composition of rain, river and sea water and the sources of dissolved elements in them. Crustal rock weathering and Sodium balance concept, transport of material to the ocean, the river pathway, the atmospheric pathway and the hydrothermal pathway.

Physical chemistry of seawater: Laws of thermodynamics and chemical equilibrium; activity scales and activity coefficients; ionic interaction and chemical speciation in seawater.

MST 103: BASICS OF GEOLOGY IN OCEANOGRAPHY

Earth systems : Origin of Earth – Moon system; Internal structure, composition, density, temperature and pressure distribution of the earth; composition of the crust; Earth's gravity and gravity anomaly of earth, magnetic fields and isostatic equilibrium; Internal constitution of earth; Earthquakes.

Ocean morphology: Major physiographic features of the ocean, continental margins, oceanic rift-ridge systems, major fault systems, abyssal plains, island arcs, marginal trenches, deep sea fans, submarine canyons and others.

Petrology: Minerals and rocks; rock classification, mineralogical and chemical compositions, textural and structural features.

Elementary idea of theory of plate tectonics: Lithosphere, asthenosphere. Plates and plateboundaries, relative motion of plates. Present day configuration of plates.

MST 104: BASICS OF BIOLOGICAL OCEANOGRAPHY

Plankton: Definition, Importance, classification based on size, mode of life and habitat. Methods of collection, estimation of standing crop.

Phytoplankton and Primary production: Organic production- Primary and secondary productions – methods of estimation of primary production. Factors affecting primary production- regional differences in (primary and secondary) production.. Light attenuation and phytoplankton photosynthesis, euphotic depth.

Marine Animals: Classification, distribution and characteristics of zooplankton, nekton and benthos. Salient features of foraminifera, radiolarian, peripheral, coelenterates, Polychaeta, mollusks, crustaceans, echinodermsprotochordates and chordates of marine inhabitants.

Seaweeds: Occurrence and distribution in India - economic importance. Life cycles of morphological and anatomical adaptations, life cycles common seaweeds and their ecological role.

Mangroves: Definition,World distribution of mangroves, osmoregulation mechanism and salt balancing in Mangrove. Morphological, anatomical and physiological adaptations of mangroves; Taxonomy and morphometric features of mangrove and mangrove associates.

MSP105: PRACTICAL: BIOLOGICAL OCEANOGRAPHY AND GEOLOGICAL OCEANOGRAPHY

1. Phytoplankton collection, preservation and population counting.
2. Identification of Phytoplankton; micro and macro algae, sea grasses, mangroves and its associates.
3. Identification of marine invertebrates and vertebrates (fish and prawns).
4. Morphometric features of the mangroves and its associates.
5. Identification of common minerals and rocks in hand specimens,
6. Identification and interpretation of common sedimentary structures in hand specimens
7. Iinterpretations of topographic and bathymetric maps
8. Identification of selective fossils
9. Submission of field visit report.

MST 201: MARINE METEOROLOGY &DYNAMIC OCEANOGRAPHY

Meteorology: Air Sea – interaction,trade wind inversion; ITCZ; monsoon trough tropical cyclones, their structure and development theory; monsoon depressions; tropical easterly jet stream. Monsoonal circulation in the Indian Ocean,

Remote sensing and its applications in marine environment: in concept and foundation of Remote Sensing (RS), energy sources and radiation principle, Energy interaction in the atmosphere, concepts of platform and sensors, remote sensing systems, types of sensors, their characteristics and application in the marine environment, satellite missions in ocean studies; Indian and Global.

Geographical Information System (GIS): Concept and historical development; components and core business of GIS. Applications of GIS in coastal and marine environment—geological/ geomophological mapping, soil mapping, land use/ land cover mapping in coastal zone .

Fluid Mechanics : Mathematical tools – Vector differentiation, Grad, Divergence, Curl, Vector integration, line integral, Application of Gauss Theorem Green's Theorem, Stokes Theorem; Multiple Integrals; Transformation of coordinate system; Curvilinear coordinates, Continuum Mechanics, Fluid properties, Units of measurement, Pressure,Density, Specific weight, specific volume, specific gravity, Viscosity, Surface tension,Newtonian and Non-Newtonian fluids. Kinematics **;** Dynamics.

MST 202: MARINE AND ESTUARINE CHEMISTRY

Dissolved gases in seawater: Dissolution of gases in seawater and their solubility; classification of dissolved gases and factors affecting their concentration in seawater; distribution of dissolved oxygen in seawater and affecting factors, AOU and oxygen minimum zone formation in the ocean, origin and consequences of ocean hypoxia.

Carbonate systems in the ocean: Acid base equilibria in seawater carbon dioxide system; parameters of carbonate systems and their distribution in the ocean; role of biological processes in affecting oceanic carbonate system; precipitation and dissolution of calcium carbonate in seawater, lysocline and carbonate compensation depth; Ocean acidification.

Micronutrients in seawater: Micro-nutrient elements (N, P, Si) in seawater, their forms, distribution and seasonal variation in the ocean. Stoichiometry of uptake and regeneration of nutrients elements and AOU.Micronutrients and primary productivity.

Estuarine chemistry: behavior of dissolved and particulate material during estuarine mixing, interaction among them and speciation of dissolved elements in the estuary; physico-chemical characteristic of estuarine sediment, anoxic sediments and pore water; heavy metals in estuaries and the processes affecting its distribution.

MST 203: MARINE GEOLOGY

Structure and composition of the oceanic crust: formation of three layered structure of oceanic crust; sea water - basalt interaction, ocean floor metamorphism.

Marine tectonics: Basic concepts and geological evidences of continental drift, sea-floor spreading and plate tectonics; mid-oceanic ridges, oceanic islands and trenches, hot spots and absolute plate motions; aseismic ridges, volcanism and plate tectonics, earthquakes and plate tectonics, continental margins and their evolution; life cycles of oceans.

Sedimentology & Stratigraphy : Clastic and non-clastic sediments and sedimentary rocks - their mechanism of formation; concept of size of clastic particles, grade scales, transformation of sediment to rock, diagenesis of sediments; sedimentary structures and their applications. Principles of stratigraphic correlations; Stratigraphic units; Laws of superposition and faunal successions; Stratigraphic correlations of marine strata.

Ichnology: ; Principles of Ichnology; Significance and applications of ichnological features, applied ichnology.

MST 204**:** MARINE ECOLOGY & MARINE POLLUTION

Intertidal ecology; adaptation of intertidal organisms; Rocky shores, sandy shores & muddy shores; Characteristics, adaptation & community organization.

Succession and sequences; Influence of planktonic life mode on species succession. Carrying capacity. Competition coefficient of phytoplankton.. Successional cycle of phytoplankton.

Adaptive mechanisms : Adaptation of plankton- structural (weight, increase of surface area, flotation) physiological (specific gravity, water content, fat content, mono and divalent ions, gas, defensive vacuoles) mechanisms.

Metals and metalloids: Sources of contamination; routes into the oceans, including river runoff, dumping, atmospheric fallout; mobility within the ocean; Interaction between trace metals and marine organisms, transport of metals across membrane: The trophic transfer of metals in marine systems. Biological features involved in metal concentration observed in marine organisms. Metal detoxification in marine organisms and prediction of metal toxicity from bioassays.Occurrence, pathways and bioaccumulation in organometallic components (Arsenic, Antimony, Mercury, Tin (IV)) in marine environment.

Organic pollutants: Types/Classes of organic contaminants and basics of chemical structures; how structures affect behavior in surface waters and sediments; Interactions with biota: transformations by microbes and animals; bioaccumulation; toxicity; assessment of sediment contamination.

Oil Pollution: Sources, impact and nature of oil pollution, ballast, introduction of invasive species through de-ballasting.

MSP 205: PRACTICAL: PHYSICAL OCEANOGRAPHY AND CHEMICAL OCEANOGRAPHY

1. Introduction to MATLAB
2. Use of MATLAB for the following assignments –
   a) Plotting of tide gauge curve from available observational data
   b) Representation of tidal fluctuation by graphical method
   c) Plotting of tidal gauge curves, cross section curve, Area-RL curve, velocity curve and computation of discharge curve
3. Determination of chlorinity by argentometric method and salinity by usingSalinometer, Refractometer. Hence compute a relation between chlorinity and salinity for estuarine water.
4. Determination of dissolved oxygen by using Winkler's method as well as electrochemical method and hence determine percentage of saturation ofoxygen in seawater.
5. Determination of carbonate, bicarbonate and free carbon dioxide in seawater from pHand alkalinity measurements.
6. Determiation of nutrients (dissolved inorganic phosphate-P ,nitrate-N and nitrite-Nandreactive silicate) in seawater by using spectrophotometric method

MST 301: COASTAL GEOMORPHOLOGY AND COASTAL ZONE MANAGEMENT

Coastal Geomorphology: Types of coastal landforms and their development; landform related to rocky and sedimentary shores; Geomorphological features of rocky shore based on composition, structure and tectonic set up; morphological variations of low-lying coast; coastal zone classification.

Beach morphology and processes: Morphological and morphodynamic classifications of beaches; barrier beaches, beach processes and dynamics,sedimentation and stability; erosion and accretion of beaches, degradation and mitigation.

Estuaries and deltas: definitions, their geomorphic features, tectonic settings, classifications and processes, degradation and mitigation.

Coastal lagoon and their formation: Morphological variations and sedimentation principle, problems in lagoonal sedimentation with special reference to Chilka lagoon., backwaters of kerala.

Tidal landforms: Tidal mashers and mudflats; their geographic and geological settings, dynamcis in tidal marsh; causes of decay of marshes and mudflats, remedial measures.

Coastal dunes:Their types, morphology, origin; dunes destruction by natural and man made activities; measures for dune protection and restoration.

Coastal zone Management: Guidelines for Coastal zone management;Impacts of construction on coastal zone, construction of jetties, breakwaters, sea walls, bulkheads groynes, revetments etc.;application of ICZM for sustainability of coastal ecosystems.Applications of GIS in coastal zone development and management.

MST 302 :MARINE MICROBIOLOGY, AQUACULTURE AND FISHERIES MANAGEMENT

Marine microbes : An Overview. Characteristics of Marine bacteria, Archaea, Eubacteria, qualitative and quantitative distributions of marine micro-organisms ;brief concept about gr+ve and gr-ve bacteria. Asexual and sexual reproduction of bacteria, endospore.

Acellular Microbes : viruses and other acellular organisms (eg., prion/virino, Satellites and Viroids). Lysogeny and Transduction.Structure and classification of virus.

Growth and Nutrition : Definition of measurement of growth, Kinetics, Nutritional types, of microorganisms – Photolithiautotrophs, Phtoorganohetreotrophs, Chemolithoautotrophs, Chemoorganoheterotrophs.Brief idea about culturable and nonculturable bacteria and their importance.Microbial activity in marine and mangrove environment and their importance in biogeochemical cycle.

Fermentation : Microbial fermentation : Different fermentation pathways – ethanolic , homolacticacid, heterolacticacid, Mixed acid &Butanediol fermentation.. Importance of fermentation.

Control of microorganisms : Disinfection and sterilization; Different physical and chemical methods for these processes.

Microbial pathogenecity : Pathogenic properties of bacteria, toxins and extracellular enzymes, seawater borne human pathogens. Antibiotics, Antimicrobial, Microcidal, Microstatic

Present status and scope of coastal fisheries and aquaculture:Different finfish and shell fish species obtained along the coastal regions in India; Use of different fishing gears for fishing operations in India; Global scenario.

Site selection : Selection of site using the criterion of topography, water supply, tides, soil characteristics, meteorological condition, types and density of vegetation, infrastructural facilities.

Layout planning and design: Layout of fish farm, design of ponds, canals, inlets and outlet structures, pumps and generators.

Pond Preparation , Stocking&Feeding management – Dry methods and Wet methods, stocking methods - Water filling, fertilization and liming.Acclimatization.Traditional, extensive, semi-intensive and intensive culture. Feeding in grow-out ponds, feeding control, Feed Tray, Feed rationing, water management and control, harvesting.
Diseases: Common diseases of marine and estuarine fin fishes and shell fishes; treatment, control and prevention of diseases.
Fish processing technology: Freezing , Drying,Canning& Reducing.

MSP 303: PRACTICAL: MARINE MICROBIOLOGY, AQUACULTURE AND FISHERIES MANAGEMENT

1. Preparation of different types of culture media, Slant and stab.
2. Sterilization Technique for different types of media and working materials.
3. Microscopic examinations, staining procedures, the grams stain;endospore staining.
4. Enumeration of microbes (by colony count) from marine sediment, sea water and aquaculture pond by Serial dilution Techniques &Coliform test by MPN method.
5. Identification and classification of microorganisms from the litters of mangroves.
6. Isolation and identification of microorganisms from spoiled fishery products of fin-fishes and shell-fishes of marine and estuarine origin.
7. Detection of unknown micro-organisms by following biochemical tests :

   (i) Sugar tests (Fermentation test), (ii) Indole test, (iii) V. P. test, etc..
8. Antibiotic sensitivity Test of microorganisms isolated from marine water and mangrove sediments.
9. Identification of larvae, fry and fingerlings of marine and estuarine fin-fishes and shell-fishes. Daily feed chart preparation from cast-net sampling data. FCR Calculation.

10. Length-Weight relationship and condition factor. Maturation of gonads and fecundity; Gut content analysis.
11. Enumeration, Isolation and identification of microorganisms and pathogens from spoiled fishery products of fin-fishes and shell-fishes of marine and estuarine origin.

MST 401: COMPUTATIONAL METHODS & MODELING IN OCEANOGRAPHY

Sampling and Data analyses : Sampling (types with case studies), presentation of data and probability distribution (normal distribution, skewness and kurtosis), students t distributions, Poisson distributions; Hypothesis testing: Significance tests, null hypothesis, student's t tests, , Z test, F test, analysis of variance chi-square tests, Correlation, regression, ANOVA, concept of curve fitting and testing validity of the expression with real time data

Modeling: Basic models of population growth: exponential and logistic.Nutrient uptake-the michaelis-menten model; Droop model for internal nutrient stores and Monod model for growth and external nutrient supply.Modeling of reaction systems, analysis of population dynamics – models of production, growth and multiple reacting species, aquatic ecosystem in estuary and ocean viz. Lotka-Volterra Model. System analysis and mathematical models in Ecology

MSP 402: PRACTICAL: COMPUTATIONAL METHODS & MODELING IN OCEANOGRAPHY

1. **Programming in MATLAB for computations of oceanographic parameters –**

- For and while loops
- More on 2-D and 3-D plotting – labels, axis control, handle graphics
- Solving algebraic and differential equations
- Eigen Values and Eigen Vectors
- Fourier analysis of tidal gauge curve
- Fourier analysis of Gauge curve and discharge curve
- Interpolation. Grid. Finite differences
- Processing and analyzing oceanographic data – Applications of Internet.
- Simple models of physical oceanography
- Basic idea of animations

2. **Use of MINITAB / SPSS for processing and analyzing oceanographic data –**

- estimation of statistics / parameter of sample / population
- Mean, variance, linear regression, curve fitting
- Quality control of temperature and salinity data, removing bad points. Filtering
- Horizontal and vertical averages
- Processing time series and global data.
- Vector time series and fields. Gradient. Property flux and its divergence

3. **Basic concepts for application and use of environmental mode**

MST 403 :SPL. PAPER (I) PHYSICAL OCEANOGRAPHY

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 – Nonlinear terms in the equation of motion – Eddy viscosity

Ocean Energy: Wave energy : future and prospects- sea states and their energy- wave growth, travel and decay – wave climate estimation- numerical and experimental modeling – Power take-off systems:

Tidal Energy: Tidal power barrage: Principal components – Ebb generation- Flood generation- Ebb generation plus pumping at high tide- two way generation-two basin schemes-turbines.

Coastal Oceanography: Coastal upwelling, Ekman circulation in shallow water, sediment movements by waves and currents in shallow water environment. Factors influencing coastal processes; transformation of waves in shallow water; effects of stratification; effect of bottom friction, phenomena of wave reflection, refraction and diffraction; breakers and surf; movement to beach material; rip currents; beach stability

Estuaries: classification and nomenclature; tides in estuaries; estuarine circulation and mixing; depth – averaged and breadth – averaged models; sedimentation in estuaries; salinity intrusion in estuaries; effect of stratification; coastal pollution; mixing and dispersal of pollutants in estuaries and near-shore areas.

Deep ocean circulation: approaches, classic scheme, Dynamic theory of abysal circulation, sources of deep and bottom water in the world ocean, Characteristics of the global conveyor belt circulation and its causes.

Ocean currents and climate: Short term cycles in ocean atmosphere system, world ocean and ice age, currents and transformation of the earth's climate, regional climate modifications.

Kinematics: Lagrangian and Eulerian methods of description of fluid flow- Lagrangian and Eulerian method- stream lines, streak lines and trajectories,
Blaton's equation, steady and nonsteady 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, Taylor's statistical theory and Kolomogoroff's similarity theory physical interpretation, application to plane motion, typical flow patterns, stream function, divergence and vorticity in different co-ordinate systems, material, local and convective derivatives.

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

linear and shear strain, rotation 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, application to air flow over mountain barriers. conservation of momentum, Navier-Stoke's equations of motion for a viscous Newtonian fluid; laminar flow of viscous incompressible fluids, Poiseuille flow, Couette flow, steady flow around a sphere

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

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

MST 403 :SPL. PAPER (II) CHEMICAL OCEANOGRAPHY

Dissolved and particulate organic compounds in seawater: their origin and distribution; ecological effects and fate in the seawater; organic carbon cycle molecular constituents of organic matter in the ocean, lipids, Amino acids and proteins in sea water, carbohydrate lignin and other low oxidation products; dissolved organic matter and their photo oxidation.

Geochemistry of marine sediments: Sources, components and classification of marine sediments; dissolved constituents in pore water; sediment interstitial water interaction and diagenesis; Redox reactions; Eh-pH diagram and their applications; organic matter accumulation in sediments; pathways of organic matter degradation and role of oxygen and nitrate, sulfate reduction; pathways of iron input into marine sediments and early diagenesis.

Biogeochemical processes in the ocean: Biogeochemical processes in aerobic and anaerobic marine environments; Primary and bacterial production in the ocean; Phytoplankton and their role in primary, new and export production. Benthic processes and burial of carbon; Harmful algal blooms and their effects on the marine ecosystem.

Particle fluxes and biogeochemical cycles: oceanic particle fluxes its variation and techniques of estimation; benthic fluxes and their distribution; formation and distribution of marine carbonates; Biogeochemical cycles of carbon, nitrogen, phosphorous and silicon in the marine environment.

Biogeochemical processes in estuaries:mechanism and pathways of organic matter transformations; humic material and its importance in estuaries; biogeochemical process related to elements like carbon, nitrogen, phosphorous and silicon in the estuarine environments and their cycles. Nutrient and trace gas biogeochemistry in the mangrove dominated estuaries.

Air-sea interactions: Aerosol and its composition, formation, transformation and transport of aerosol; properties of the sea surface microlayer; Air-sea exchange of gases. production of radiatively active gases in the marine environment and its effect on atmospheric composition and climate; Inter-relationships between ocean circulation, primary productivity and chemical composition of the atmosphere & the ocean.

Radioactive tracers / Stable isotopes in marine chemistry: Radioactive decay series and their application to geochronological studies; application of stable isotopes in biogeochemical studies and uses of chemical tracers in oceanography. Radioactive tracers in estuarine chemical studies.

Blue carbon: Carbon sequestration in the coastal systems, Contribution to the global carbon budget, Carbon sequestration potential in the Indian Sundarbans.

Chemistry of marine natural products: biomedical Aspects**;** chemical and pharmacological properties of bioactive substances in marine organisms, carbohydrates and their derivatives in red and brown algae, aliphatic acids and their derivatives in marine organisms, steroids and their use as biomarkers, nitrogenous compounds in invertebrates, nucleosides from sponges, biopolymer.

Analytical instrumentation: Errors and precision of analytical methods used in chemical analyses. Analytical techniques and application of different instruments like AAS, GC, HPLC, TOC analyzer, coulometer, nutrients in chemical oceanographic studies.

MST 403: SPECIAL PAPER: (III) GEOLOGICAL OCEANOGRAPHY

The Ocean Basins, Structure & Evolution: TheShape and main features of ocean basins, Ocean Ridges – Ridge topography, The deep ocean floor –Abyssal plains, seamounts, Aseismic ridges, The Evolution of ocean basins.Indian basins- Bombay high, Bengal basin, Andaman basin and Krishna-Godavari basin

The Structure and Formation of Ocean Lithosphere : Formation of oceanic lithosphere, segmentation of oceanic spreading axes; a plausible model for lithospheric growth.

Hydrothermal Circulation in Oceanic Crust : The nature of hydrothermal circulation. Chemical changes during hydrothermal circulation; Black smokers, white smokers and warm water vents.

Igneous Petrogenesis: Genesis of magma in ocean floor; phase diagrams of basaltic rocks; metasomatism and hydrothermal reactions.

Structural Geology: Diastrophic and non-diastrophic structures; mechanism of folding and faulting; concept of salt diapirism.

Ocean floor metamorphism: Definitions, concept, importance of ocean floor metamorphism for the genesis of sulphide deposits.

Principles of substitution of major elements by trace elements: Goldschmidt's laws; Ringwood's corrections; geochemical classification of trace and major elements (lithophile, siderophile, chalcophile, atmophile and biophile); composition of sea water through space and time. Geochemical cycles of oxygen, carbon, halides, phosphates etc.

Application of stable and radioactive isotopes in marine geology: Geochronology of following systematics: K-Ar, Rb-Sr and C-14 for dating of oceanic rocks.
Sea Bed Deposits: Minerals and rocks : Terrigenenous, biogeneous and chemogeneous deposits; Placer deposits of continental margins; seabed manganese nodules- their occurrence and distribution, physicochemical characteristics, morphology, growth rate, mineralogy, chemistry and origin; Manganese crust, hydrothermal vents and hydrothermal sulphides;

Palaeocanography and sea-level changes: Sediments and palaeoceanography, changes in sea-level; different time scale in sea-level changes; The post glacial rise in sea-level; The growth of an ice-sheet Antarctica; the migration of climatic belts; the effect of plate-techtonic processes on sea-level; major transgression and regressions.

Petroleum and natural gas: Origin, occurrence and structural control of petroleum and natural gas reservoirs. Gas hydrates. Brief idea on Indian occurrences.
Coal: Processof coalification, grades and ranks. Origin and distribution in India

MST 403: SPL.PAPER (IV) BIOLOGICAL OCEANOGRAPHY

Marine and estuarine living resources: Seaweeds, fin fish and shell fish resources: types, culture, management, livelihood generation, marketing, concept on cost-benefit analysis **;**Phytoplankton and zooplankton: culture, importance, ecological and economic benefits.

Zooplankton Grazing : Components of Grazing. Estimation of Grazing rates. Grazing and the dynamics of phytoplankton.

Marine Nekton : Composition of oceanic nekton, Adaptation of oceanic nekton, Ecology of nekton, Ooze forming marine organisms;

Ocean Hypoxia: Distribution of hypoxia in the oceans; causes; Case studies; Harmful Algae Bloom: Definition; Causative organisms; Impact; Relation with Eutrophication.

Marine algae: Algae and methodology – Basic biological features of phytoplankton cells. Light attenuation and phytoplankton photosynthesis; The measurement of photosynthesis in natural populations of phytoplankton. The role of trace metals in regulating phytoplankton growth;

Dinoflagellates: Features, nutrition, asexual and sexual reproduction and cyst formation, bloom formation, red tide, Diniflagellate toxin and its antidote.

Population Dynamics : Size and scale in phytoplankton ecology. Growth processes of phytoplankton populations – Exponential and logistic growth. Growth and nutrients uptake,

Michalis-Menten, Droop and Monad Models of Nutrient uptake and growth. Loss processes – perennation, mortality and washout.

Mangroves: Mangrove and mangrove ecosystem – A brief review. Protective and economic roles played by the mangroves , Present status and stresses on the mangrove and mangrove ecosystem of the Indian sunderban. Alarming situation and action plan of sunderban mangrove. . Adaptation, threats and conservation strategies with global and regional case studies **;** Effect of physico-chemical variables, climatic factors on mangroves;

Coral reefs : Distribution and limiting factors; Coral structure and diversity; Nutrition and productionin reefs; Production estimates; Formation and growth of reefs; Coral predators and predation on reefs; Destruction and conservation of reefs.

Deep-Sea Ecology: Faunal composition and their adaptation to deep sea environment; Species diversity and Biomass; Rates of biological processes; hydrothermal vents and cold seeps; Chemosynthetic production; Shallow vents and cold seeps; Environmental features of sulphide communities;

Role of Algae in Bio-geo-chemistry: Cyanobacteria and the origin of an Oxygen-Rich Atmosphere. Algae and the carbon cycle – Algae and organic carbon sequestration, The role of algae in carbonate formation, impact of modern Carbon Dioxide level on algal photosynthesis, Carbon concentration mechanism of cyanobacteria, Carbon concentration mechanism of Eukaryotic algae, Algae and the nitrogen cycle, Algae and the sulfur cycle, Iron limitation of algal growth in the oceans.

UV radiation: Characterization,Different types of UV-radiations and its effects on marine biota.
Genetics: Transcription, translation, DNA finger printing and barcoding, genomics, proteomics and functional proteomics, concept of BET test, GMO etc.

Recent Advances in Marine Biotechnology: Protein biomarkers for paralytic shelfish toxins. Characteristics of deep sea microorganisms adapted to extreme environment.Bioreactor technology for mass cultivation of photoautotrophic microalgae.Bioactive metabolite from seaweeds.

CBCC offered by Dept. of Marine Science:

INTRODUCTION TO MARINE ENVIRONMENT

Earth system , hydrosphere and oceans, Hydrological cycle.
Global ocean basin and their dimension.
Physical characteristics of the ocean . Estuary classification and its characteristics ;
Physical properties of seawater and their distribution in the global ocean.; Current, waves and tides in the ocean.
Composition and stoichiometry of seawater. Major, minor and trace elements; Dissolved gases and carbonate system in the seawater. Air-sea interactions.
Distribution of life in the marine environment and classification of marine organisms.
Division of the marine environment. Pelagic realm and their subdivision; Benthic realm and their subdivisions.
Primary and secondary production in the ocean. Plankton: definition, classification ; methods of collection., Relative abundance of plankton in marine environment,. Mangroves : definition, adaptation, protective and economic role of mangrove. .