M.Sc. (Oceanography)

Course Curriculum & Syllabi – 2022-23

Department of Marine Sciences, Berhampur University

Introduction:

Department of Marine Sciences was established in the year 1978 in Berhampur University. This is the only University in the state which offers M.Sc., M.Phil. and Ph.D./D.Sc. degree in the subject of Marine Sciences covering both Oceanography and Marine Biology. The genesis for such a department was to produce quality manpower in the field of Marine Sciences, both through teaching and R&D activities, to meet the demand of the state as well as the country. The Department of Marine Sciences offers two degrees, M.Sc. in Oceanography and M.Sc. in Marine Biology separately. Candidates with B. Sc. in either Physical sciences/B.E./B.Tech. with Physics as one of the core subjects are eligible to take admission in Oceanography while students with B.Sc. in Biological Sciences are eligible to take admission in Marine Biology. Admission to these degrees is through entrance tests. The Courses of Studies for Master's Degree (M.Sc.) in Oceanography and Marine Biology are under Choice Based Credit System (CBCS) effective from 2020-2021 Academic Session.

Faculty Members:

1. Dr. Pratap Kumar Mohanty, Professor (Oceanography)
2. Dr. Shesdev Patro, Assistant Professor (Marine Biology)
3. Dr. Suchsmita Srichandan, Assistant Professor (Marine Biology)
4. Dr. Nibedita Behera, Assistant Professor (Oceanography)

Facilities:

The Postgraduate Department of Marine Sciences has following facilities available for students and research scholars:

Seminar and Library:

The Department has an independent Seminar Hall with state of art audio-visual system, where weekly student presentation seminars are conducted under the supervision of a Faculty-in-Charge. The Departmental library has more than 1200 books and several journals / newsletters / periodicals related to the subject of marine sciences.

Computing facility:

The department has a centralized Computer Laboratory well equipped with internet facility, PC and Servers. Softwares *viz*. ERDAS Imagine, Arc-view, MATLAB, Surfer, Statistica and other statistical packages are preloaded with the systems and accessible by students.

Laboratories:

The Department has six practical laboratories viz, Marine Biology, Marine Microbiology, Marine Chemistry, Marine Geology, Physical Oceanography & Meteorology and Remote Sensing.

About the Syllabus:

The syllabus is designed as per CBCS in accordance with the guidelines provided by the University Grant Commission (UGC). The Master of Science in Oceanography and Master of Science in Marine Biology are full time two years programmes with four semesters each. The 1st Semester is common for both Oceanography and Marine Biology spanning the period from June to December and 2nd Semester from January to May in the first academic session. The 3rd Semester commence from June to December and similarly the 4th Semester from January to May in the subsequent academic session. The uniform nature of credits specified for the Master's Programmes describe the equitable weightages of various courses. The number of credits along with grade points that a student satisfactorily completed, measures the performance of the student. Overall satisfactory progress and completion of course is subject to a student's maintaining a minimum Cumulative Grade Point Average (CGPA), as well as minimum grades in different subjects as per the syllabus. The description and layout of Credit Distribution for each of the Course programme is detailed below:

- Total number of Semesters is **Four.**
- Each Paper comprises of **04 Credit points.**
- Each Practical Paper comprises of **03 Credit points.**
- Each Theory Paper comprises of **100 Marks.**
- Each Practical Paper comprises of **50 Marks.**
- Project comprises of **100 Marks**
- Number of Core Papers (Theory) are **12 (Spread over all four Semesters).**
- Number of Elective Papers (Theory) are **03 (In 3rd and 4th Semesters).**
- One CBCT Paper (Theory) in **3rd Semester (Mandatory)**
- Number of Practical Papers are **06 (1st, 2nd and 3rd Semesters).**
- Number of project/dissertations is **01** (**4th Semester**)
- Core papers (12) are **Mandatory with no choice.**
- Elective papers (03) are **Mandatory with Choice Departmentally.**
- Value added courses (VAC) (02) are **non-credit courses in 2nd and 3rd semester**
- Add-on Course (AC) (01) is **non-credit course in 4th Semester**
- Total number of Papers is **23 including 01 Project Work in 4th Semester excluding VAC and AC.**

- Total number of Credits is **88 Credit points.**
- Total Marks for all **04 Semesters is 2000.**

Note on CBCT: Marine Biology students may opt for CBCT courses offered by other bio-science departments of the university while Oceanography students may opt for CBCT courses offered by physical science departments of the university

Guidelines for value added courses

Value Added Course is not mandatory to qualify for any programme and shall be offered as non-credit course. Value Added Courses completed by a student shall be reflected in the mark sheet as non-credit course in the 2nd and 3rd semester. It is a teacher assisted learning course open to students of the concerned department without any additional fee. However, students shall pay the prescribed examination fee and register along with other courses in that particular semester. A student will be permitted to register only one Value Added Course in a Semester. The course can be offered only if there are at least 10 students opting for it where the total strength is 50. In case of lower strength, it will be proportionate.

Syllabus for M.Sc. (Oceanography)

The Syllabus has been designed covering practical/dissertation/field works/seminars etc., wherever applicable. A list of Text Books is provided against each paper for all Semesters. However, students may also make use of authentic online sources for their benefit. A student is advised to deliver at least one seminar talk on a selected topic based on the syllabus during each semester (weekly-at least one Seminar by one of the students, to cover all students). During the course work, students are allowed to interact with the faculty to clarify their doubts, if any. They may be also assessed through weekly tests (duration: 45 minutes) of multiple-choice questions and short answers (individual or all subjects of the Semester, Combined) as appropriate.

General Course Framework & Structure

SEMESTER I- Total Credits- 22 & Core papers: 04; Elective Papers: Nil; Practical: 02

Course Code	Title of the Paper	Marks			Credit
		IA	Exam	Total Mark	
MARO C101	Introduction to Earth, Ocean, Atmosphere and Climate	20	80	100	4
MARO C102	Fundamentals of Physical, Chemical, Geological Oceanography and Marine Meteorology	20	80	100	4
MARO C103	Fundamentals of Marine Biology and Pisciculture	20	80	100	4
MARO C104	Basic Mathematics, Statistics and Computer Programming	20	80	100	4
MARO P105	Practical I on Paper C101 and C102	-	50	50	3
MARO P106	Practical II on Paper C103 and C104	-	50	50	3
Total Marks/Credit (C 04 + Practical 02)				**500**	**22**

**Semester I is common for both Oceanography and Marine Biology students*

SEMESTER II- Total Credits- 22 & Core papers: 04; Elective Papers: Nil; Practical: 02; Non-credit VAC-1: 01

Course Code	Title of the Paper	Marks			Credit
		IA	Exam	Total Mark	
MARO C201	Geophysical Fluid Dynamics and Numerical Methods	20	80	100	4
MARO C202	Ocean-Atmosphere Interaction and Ocean Dynamics	20	80	100	4
MARO C203	Waves, Tides and Storm Surges	20	80	100	4
MARO C204	Coastal Oceanography and Estuarine Dynamics	20	80	100	4
MARO P205	Practical I on Paper C201 and C202	-	50	50	3
MARO P206	Practical II on Paper C203 and C204	-	50	50	3
Total Marks/Credit (C 04 + Practical 02)				**500**	**22**
MARO VAC-I	Certificate Course on Value Addition of Marine Fishery Product	Non-credit			

SEMESTER III- Total Credits- 22 & Core papers: 02; Elective Paper: 01;CBCT paper:01 Practical: 02; Non-credit: 01

Course Code	Title of the Paper	Marks			Credit
		IA	Exam	Total Mark	
MARO C301	Advanced Marine Meteorology	20	80	100	4
MARO C302	Remote Sensing and Geographical Information System (GIS) in Marine Sciences	20	80	100	4
MARO E303	Ocean Wave and Tide Modelling	20	80	100	4
MARO E304	Marine Geochemistry	20	80	100	4
MARO CT300	Environmental Impact Assessment (EIA) and Management Plans	20	80	100	4
MARO P305	Practical I on papers C301 and C302	-	50	50	3

Course Code	Title of the Paper	Marks			Credit
		IA	Exam	Total Mark	
MARO P306	Practical II on Data collection onboard research vessels and preparation of Cruise Report	-	50	50	3
Total Marks/Credit (C 02 + E 01+CT01 + Practical 02)				**500**	**22**
MARO VAC-II	Certificate Course on Marine Litter Monitoring and Management	Non-credit			

NOTE:

In Semester-III, a student is allowed to opt for one elective (E) from E303 and E304 along with two core courses (C301 & C302) and CBCT course (CT 305). A student graduated with subject background in Physics and Mathematics/Engineering may opt for E303 while with Chemistry and Geology background can opt for E304.

SEMESTER IV- Total Credits- 22 & Core paper: 02; Elective Papers: 02; Project: 01; Add-on course: 01

Course Code	Title of the Paper	Marks			Credit
		IA	Exam	Total Mark	
MARO C401	Polar Oceanography and Climate	20	80	100	4
MARO C402	Marine Biogeochemical Processes	20	80	100	4
MARO E403	Numerical Weather Prediction	20	80	100	4
MARO E404	Ocean Circulation Modelling	20	80	100	4
MARO E405	Marine Pollution	20	80	100	4
MARO E406	Geomorphology and Geodynamics	20	80	100	4
MARO P407	Project Work, Dissertation & Open Viva-Voce	-	100	100	6
Total Marks/Credit (C 02 + E 02 + Project 01)				**500**	**22**
MARO AC	Cultural Heritage of South Odisha	Non-credit			

NOTE:

- *A student is allowed to opt for any two electives (E) in a group of E403 & E404, E405 & E406 along with the two core courses (C401 & C402).*

Details of Syllabus
Semester- I

Semester: First Semester	**Course Name:**	Introduction to Earth, Ocean, Atmosphere and Climate
Course No.: MARO C101	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide the interdisciplinary overview about the domain of Oceanography	*Students understand the basics and gain fundamental concepts related to the ocean, atmosphere, earth and climate*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	**Earth:** Earth and the solar system, Modern theories on the origin of the Earth and the planetary system, Kepler's laws of planetary motion, Geological Time Scale, Theories about the origin of life, Earth's gravity and magnetic fields and its thermal structure, Concept of Geoid and Spheroid. Weathering, Erosion, Transportation and deposition of Earth's materials, Formation of soil, Sediments and sedimentary rocks, Physiographic features and river basins in India. Basic concepts of seismology and internal structure of the Earth. Earthquakes and their causes.	20
Unit 2	**Ocean:** Ocean and Sea, Major Oceans of the world and their dimensions, Seafloor features, Shoreline, Continental Shelf, Continental slope, Continental Rise, Mid ocean ridges and Hydrothermal Vents. Methods for mapping bottom topography, Light in the sea, Color of the sea, Sound in the sea. Major Ocean Expeditions: Challenger Expedition, METEOR and DISCOVERY Expeditions, International Geophysical Year (IGY), International Indian Ocean Expedition (IIOE), Tropical Ocean Global Atmosphere (TOGA), World Ocean Circulation Experiment (WOCE), Joint Global Ocean Flux Studies (JGOFS). Monsoon Experiments in Indian Ocean (MONEX, BOBMEX and ARMEX).	20
Unit 3	**Atmosphere:** Atmosphere and its composition, Global distribution of atmospheric mass, Zonal wind, Meridional wind. Geopotential height, Vertical velocity and the mean meridional circulation. Inter tropical convergence zone (ITCZ), Potential temperature coordinates. Global distribution of water vapour, Precipitation, Surface fluxes due to turbulence, Effects of large-scale eddies on the zonally	20

Units	Contents	Hours/ Semester
	averaged flow.	
Unit 4	**Climate:** Weather and Climate, Global climate and the general circulation, Global climatic features, Global teleconnections, Pressure oscillations and teleconnection patterns. The Southern Oscillation and El Niño and La Nina, ENSO mechanisms, Teleconnections with ENSO, Extratropical teleconnection patterns, North Atlantic Oscillation, North Pacific Oscillation, Arctic and Antarctic Oscillation, Zonally symmetric oscillations, Tropical–extratropical teleconnections, Inter-annual to inter-decadal oscillations. Indian Monson - Indian Ocean Basin Mode (IOBM), Indian Ocean Dipole (IOD).	20

Suggested Text / References

1. Kent C. Condie, Earth as an Evolving Planetary System, Academic Press.
2. Naotatsu Shikazono, Introduction to Earth and Planetary System Science: New View of Earth, Planets and Humans, Springer.
3. H. Jay Melosh, Planetary Surface Processes, Cambridge University Press.
4. Pickard G.L. and W.J. Emery, Descriptive Physical Oceanography - Pergamon Press (Latestedition).
5. Lynne D. Talley, G.L. Pickard, W.J. Emery and James Swift, Descriptive Physical Oceanography: An Introduction- Elsevier (Latest edition).
6. John A. Knauss. Introduction to Physical Oceanography, Waveland Pr. Inc.
7. Wallace and Hobbs. Atmospheric Science (Latest Edition), An Introductory Survey, Elsevier.
8. An Introduction to the General Circulation of the Atmosphere, D. A. Randall, Colorado State University Press, 2005.
9. Marshall. John, and R. Alan Plumb. Atmosphere, Ocean, and Climate Dynamics: An Introductory, Academic Press.
10. Observed Global Climate, Geophysics Series, Volume 6: Edited by M. Hantel, Springer, 2005.

Semester: First Semester	**Course Name:**	Fundamentals of Physical, Chemical, Geological Oceanography and Marine Meteorology
Course No.: MARO C102	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide the basic knowledge about the four important components of Oceanography; physical, chemical, geological and	*Students who join Oceanography from various branches of Physical Science/engineering get an exposure to the basic components of Oceanography, which encourage them later to*	

marine meteorology	*choose their specialization depending on their fields of interest*

Course Details

Units	Contents	Hours/ Semester
Unit 1	**Physical oceanography:** A historical background, Temperature, Salinity, conductivity, effect of temperature, salinity and pressure on density, Potential density and specific volume. Specific volume anomaly and thermosteric anomaly. Adiabatic changes of sea water. Properties of sea water, Basic pure water characteristics, molecular, colligative, optical and acoustical properties of sea water. Horizontal and vertical distribution of temperature, salinity and density in the oceans. Heat budget equation. **Circulations and currents:** Oceanic mixed layer, barrier layer and thermal inversion. Seasonal and permanent thermocline, Halocline and Pycnocline. Heat and fresh water transports, Conservation of salt and heat, Water type and water masses, T-S diagram, Bottom-Deep-Intermediate and surface water masses. Thermohaline and Wind driven Circulation, World Ocean circulation – Major Ocean currents, Equatorial Currents, Undercurrent, Antarctic Circumpolar Current and Western and Eastern Boundary Currents, Langmuir Circulation. Currents and Circulation in the Indian Ocean, Arabian Sea and Bay of Bengal during southwest and northeast monsoon seasons.	20
Unit 2	**Marine Chemistry** Historical perspectives, Symbols and units used in chemical oceanography, Composition of Sea Water, Major nutrients, Geochemical balance of the oceans, Residence time, 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, Chlorinity and salinity, Practical salinity scale, Radioactive nuclides, Residence times of elements in the sea water, Dissolved Gases(other than CO_2) in Sea Water, Solubility of gases in seawater, Air-sea gas exchange and processes affecting their distribution, Dissolved oxygen in the ocean, CO_2 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	20
Unit 3	**Marine Geology:**	20

Units	Contents	Hours/ Semester
	An overview, Geomorphology of ocean floor: Abyssal plain, oceanic island, sea mounts, trenches, Island Arc, Atolls and Guyots. Submarine canyons and mid oceanic ridges. Sea floor spreading and Plate tectonics. Salient features of Indian Ocean floor: Bathymetric maps, Different methods of exploring ocean floor, Definition and classification of coast, Coastal erosion, Beach sediments and morphology, weathering of beach materials. Alongshore and cross-shore sediment transport, Beach profile, Factors controlling geomorphology of beaches.	
Unit 4	**Marine Meteorology** An introduction. Earth's rotation and revolution around the sun, seasonal changes, Composition of the atmosphere, Vertical distribution of temperature and atmospheric layers, Radiation balance of the earth-atmosphere system, Greenhouse effect. Relative, absolute and specific humidity, Mixing ratio, Dew point temperature, Dry and wet bulb temperature, Cloud formation and its classification, Indian monsoon flow, tropical cyclones – cyclogenesis, classification, frequency of occurrence and land fall.	20

Suggested Text / References

1. Pickard G.L. Descriptive Physical Oceanography, Pergammon Press Oxford, 1963.
2. Open University of U.K. Sea water: its composition, properties and behaviour. Pergammon Press.
3. LynneD.Talley,G.L.Pickard,W.J.EmeryandJamesSwift(2011):DescriptivePhysicalOceanography: An Introduction- Elsevier (6th edition,2011).
4. Sverdrup H.U., Johnson M.W. and Fleming R.H (1958): The Oceans: their physics, chemistry and general biology, Prentice Hall Inc., New Jersey,1958.
5. A.S.N. Murty & V.S.N. Murty. Physical Oceanography, A.P.H. Publishing Co, New Delhi, 2010.
6. M. Tomczak. Regional Oceanography. Daya Publishing House, New Delhi
7. Open University of U.K. Ocean circulation. Pergammon Press.
8. Fairs Rhode Bridge. Encyclopodia of Atmospheric Sciences.
9. Wallace, J. M., & Hobbs, P. V., 2006. Atmospheric science: an introductory survey (Vol. 92). Academic press.
10. J.S. Fein and P.L. Stephens, Monsoons, Wiley Interscience.
11. World Meteorological Organisation, International Cloud Atlas.
12. X.Rodo and F.A. Comin, Global Climate. Springer-Verlag.
13. G.G.Tarakanov, Tropical Meteorology, MIR Publishers.
14. Bird, E.C., Coasts – An introduction to systematic geomorphology.
15. Sheppard,F.P., 1967, Submarine Geology.

16. Shepard F.P., The Earth beneath the Sea.
17. Lauff,G.H., Estuaries
18. P.D.Komar, Shore Processes and Sedimentation.
19. Ippen,A.T., Estuary and coastline hydrodynamics.
20. Johnson,D.W., Shore processes and shoreline development.
21. Open University of U.K., Sea water: its composition, properties and behavior. Pergammon Press.
22. Martin, D.P., Marine Chemistry, Vol 1 & 2.
23. Riley J.P.& Chester, R, Introduction to Marine Chemistry.
24. Riley,J.P.& Skirrow,G, Chemical Oceanography.

Semester: First Semester	**Course Name:**	Fundamentals of Marine Biology and Pisciculture
Course No.: MARO C103	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide the basics about biological oceanography	*This course helps a student to develop their analytical skill so that they learn how to apply the basic knowledge in Physics, chemistry and geology of the ocean to biology of the ocean*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	**Introduction to marine environment:** Sea as a biological medium and role of environmental factors including light, salinity, temperature, pH, turbidity, dissolved oxygen, nutrients, trace elements, Major divisions of marine environment (Pelagic and benthic), Pelagic environment (neretic and oceanic), benthic environment (supralittoral, littoral, sublittoral, bathyal, abyssal and hadal) **Life in the sea and coastal regions** Classification of marine flora and fauna (Plankton, Nekton, Pleustone, Benthos, seagrass, mangrove, salt marsh, seaweed)	15
Unit 2	**Plankton** Classification of planktons based on category, size, shape, mode of life cycle and habitat. *Phytoplankton*: Taxonomic classification of phytoplankton, Methods of phytoplankton collections, preservation and identification. Methods for estimation of standing stock in marine environment. *Zooplankton*: Taxonomic classification of zooplankton, Methods of zooplankton collections, preservation and identification. Methods for estimation of their biomass in marine environment.	20

Units	Contents	Hours/ Semester
Unit 3	**Benthos** Classification of benthic organisms, The intertidal region- rocky shore, sandy and muddy shore, Salient features of different shores and adaptations of organisms living in rocky, sandy and muddy shores; deep sea benthos and their adaptations. Methods of collection, preservation and estimation of standing crop and biomass of benthos.	15
Unit 4	**Marine Flora of India** Seagrass, mangrove, salt marsh and seaweed, their distribution, ecological and economical significance **Pisciculture** Present status of pisciculture in India, aquatic environment management, aquatic animal health, business management, fish nutrition and feed technology, fisheries economics, sea ranching	25

Suggested Text / References

1. Peter Mc Roy, C. and G. Helterinch., 1977. Seagrass Ecosystems. A Scientific Perspective. Marael Dekker Inc. New York.
2. Parsons, T.R., M. Takahashi and B Hargrave (2nd Ed.s) 1977, Biological oceanography Processes Pergamon Press, Oxford.
3. Chapman, V.J. & D.J. Chapman, 1980, Seaweeds and their uses, Chapman and Hall, London Ltd.
4. Spoel S. Vander and Heyman, R.P., 1983. Comparative atlas of Zooplankton biological patterns in the oceans. Springer-Verlag, Berlin.
5. Lalli C.M., Parson, Parson, C.R., 1997, Biological oceanography: An introduction, Elsevier Butterworth-Heinemann
6. Tomas, C.R., 1997. Identifying marine phytoplankton. Acaedmic press, 858p
7. S.Z. Qasim., 1998. Glimpses of the Indian Ocean, IBH Press, New Delhi.

Semester: First Semester	**Course Name:**	Basic Mathematics, Statistics and Computer Programming
Course No.: MARO C104	**Credits:** 04	**Core/Elective:** Core
Course Objective: *To provide the basics about application of mathematics in ocean studies*	**Student Learning Outcome** *Students learn the application of statistics and basic mathematics in ocean studies while programming language and knowledge on software and tools help them to pursue interest in data analysis and numerical modelling of ocean-atmosphere system.*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	**Basic mathematics:** Laws of indices, Logarithms, Linear and parabolic functions, Permutation and combination, Arithmetic and geometric progression. Differentiation, Application of differentiation - Velocity, acceleration, related rates. Application of integration to growth and decay problems, Matrics - Addition, subtraction, multiplication. Vector addition - Dot and cross products.Cartesian and spherical coordinate systems, distance between two points, equation of a circle, parabola and ellipsoid in their simplest form.	20
Unit 2	**Basic Statistics:** Methods of summarization of statistical data: Averages, Dispersion, Skewness and Kurtosis. Correlation and Regression: Linear, Partial and Multiple Correlation. Curve fitting: Method of Least Squares, Linear and Multiple Regression. Probability and Distributions: Random variables, Expectations and moments. Binomial, Normal, Exponential, Weibull, Rayleigh and Log-normal Distributions. Sampling distributions: Standard Error, Chi-square, Students "T" and "F" distributions. Confidence interval for the mean and proportions. Tests of Significance concerning Mean, Proportion and Variance.	20
Unit 3	**Computer programming:** Introduction to Computer programing, Programming Languages and Software and Tools applicable to Oceanography and Marine Biology. FORTRAN Programming (90/95): History and importance of Fortran, Versions, Programming steps, Variables and Data types, Input and Output, Operators, Functions, Subroutines, Control statements, Loops, Arrays, Programming steps, Flow charts and Algorithms, Selected numerical algorithms.	20
Unit 4	**Software and Tools:** Introduction to Golden Software – Grapher and Surfer, MATLAB, Ferret, GMT. Geographical Information System (GIS) – Applications to Oceanography and Marine Biology. Data Processing and Plotting principles and methods using different Software and Tools. Concept of Database and Applications.	20

Suggested Text / References

1. Narayan, S. (1993): Mathematical Analysis. Sultan Chand and Co.
2. Gilbert Strang (2012): Linear Algebra and its applications 4th Edition.
3. Ravindra B. (2012): Linear Algebra and Linear models.
4. Murray, An Introduction to differential equations.
5. Sendor I, Elements of partial differential equations.
6. Gupta, S.P., Statistical Methods.
7. Gupta and Kapoor (2000): Fundamentals of Mathematical Statistics.
8. Zar, J.H. (2003): Bio-statistical Analysis. 4th edition. Pearson Education.

9. Croxton F.E. and Cowden D.J. (2000): Applied General Statistics. Prentice Hall.
10. Kendall M.G. and Stuart A., The advanced theory of statistics. Vol. I &II.
11. Emery and Thomson, (2001): Data Analysis Methods in physical oceanography, Permagon Press.
12. Babu Ram and Pearson (2009), Engineering Mathematics.
13. Computer Programming in FORTRAN 90/95, (1997): V. Rajaraman, Prentice Hall of India, New Delhi.
14. Computer Oriented Numerical Methods, Fourth Edition, V. Rajaraman.
15. FORTRAN 90/95 for Scientists & Engineers, 1998 - S.J. Chapman, Mc-Graw Hill.
16. Grapher, Users Guide, Golden Software, Inc. Colorado 80401-1866, U.S.A.
17. Surfer, Full Users Guide, Golden Software, Inc., Colorado 80401-1866, U.S.A.
18. S.N. Alam & S.S. Alam: Understanding MATLAB: A Text Book for Beginners,I.K. International PublishingHouse.
19. FERRET USER'S GUIDE Ver sion 6.02 NOAA/PMEL/TMAP Steve Hankin Jon Callahan, Ansley Manke Kevin O'Brien, Jing Li April 26, 2007.
20. THE GENERIC MAPPING TOOLS GMT API Documentation Release 5.4.5 P. Wessel, W. H. F. Smith, R. Scharroo, J. Luis, and F. Wobbe Jan 03, 2019
21. Francis Harvey, (2015): A Primer of GIS, Fundamentals of Geographic and Cartographic Concepts. ISBN-13: 978-1462522187.
22. Andrew Skidmore, (2017): Environmental Modelling with GIS and Remote Sensing. ISBN-13: 978-1138430594.

Semester: First Semester	**Course Name:** Practical I	
Course No.: MARO P105	**Credits:** 02	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide the hands-on training on some of the basic instruments and tools used in physical, chemical, geological oceanography and meteorology	*Students learn the mechanisms of various instruments, their observation and analysis techniques.*	

Course Details

Units	Contents	Hours/ Semester
	Practical session on paper C101 and C102 1. Digitization of the world map (Printed Map/Charts or Google Earth) using Cartesian coordinates and plotting on graph paper indicating the major world oceans based on their geographical boundaries. 2. Plotting of the bathymetric contours using digitized depth values from a published hydrographic chart or using digital data (open sources) on a graph paper for the Indian Ocean. 3. Preparation of a composite chart of Indian Seas (400 to 1000E, 00	

Units	Contents	Hours/ Semester
	to 300N) indicating the major rivers (plot using their geographic coordinates on a graph paper) and the daily atmospheric pressure contours (synoptic)during any given month (January to December). Tabulate the monthly river discharges to the sea using open source data. 4. Principles and functioning of Global Positioning System (GPS) and preparation of the boundary map for a local site (say Berhampur University Campus) and identification of the major installations, buildings etc.using their co-ordinates of your survey and compare results with Google Map. 5. Principles and mechanisms of different meteorological instruments and measurements of local weather parameters such as air temperature, pressure, wind, humidity and rainfall at a given location. 6. Principle and mechanism of various marine geological instruments. 7. Estimation of grain size parameters by mechanical sieving,heavy mineral separation by gravity method and calcium carbonate in marine sediments. 8. Preparation of synoptic counter maps (spatial distribution) of sea surface temperature and salinity for a given month (January to December) in the Indian Seas (400 to 1000E, 00 to 300N) manually using synoptic data from open sources. 9. Plotting of vertical profiles (monthly variability) of sea surface temperature and salinity for a given location (January to December) in the Indian Seas (400 to 1000E, 00 to 300N) manually using data from open sources. 10. Preparation of a chart (use a printed world map showing the land boundaries) depicting World Ocean circulation: Major ocean currents -Equatorial Currents, Antarctic Circumpolar Current and Western and Eastern Boundary Currents. 11. Preparation of charts for north-east and south-west monsoon wind flow (contours of monthly wind speed and direction with arrows) in the Indian Ocean. 12. Plot time-series of sea surface wind speed & direction; sea surface temperature and current (speed & direction) at a given location during a selected period (January to December) in the Indian Seas (400 to 1000E, 00 to 300N) manually using satellite data from open sources. 13. Determination of salinity of sea water, Alkalinity of seawater, dissolved oxygen and measurement of pH of seawater.	

Semester: First Semester	**Course Name:**	Practical II
Course No.: MARO P106	**Credits:** 02	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide the hands-on training on some of the basic instruments and tools used in biological oceanography and statistics	*Students learn the mechanisms of various instruments used for study of biology of the ocean and analysis techniques using statistics.*	

Course Details

Units	Contents	Hours/ Semester
	Practical session on paper C103 and C104 1. Methods of marine Plankton collection, preservation and analysis 2. Identification of phytoplankton (Diatoms and Dinoflagellates) and Zooplanktons, locally available sea weeds and sea grasses 3. Methods of benthos collection, preservation and analysis 4. Identification of marine benthos 5. Hands on experience in FORTRAN for computing simple statistical estimates such as mean, moving average and standard deviation (use a subroutine here) using time-series temperature (SST – Sea Surface Temperature), salinity, estimated standing crop & biomass, surface wind and current data. Repeat this exercise for 30 input data sets available in 30 different files and save the data in a single as well as individual output files. 6. Demonstrate (Fortran) distance between two spatially apart input data points and continue for a set of 10 such data pairs, estimate path of 10 circles having equivalent diameters (i.e. estimated distances). Compute correlation coefficient between a sample time-series wind (speed only) data from two neighboring locations in the Bay of Bengal, and fit a straight line for the same data (simple linear regression). 7. Computation of mean monthly wind and current data using Fortran Programming for the Indian Seas (400 to 1000E, 00 to 300N, choose 10 grid size) for a given month (January – December) using available Remote Sensing data from open sources. 8. Plot the above outputs (Sl. No. 5 to 8) using Grapher and Surfer (Golden Software) appropriately. 9. Use MATLAB instead of FORTRAN for two selected data sets as above (Sl. No. 5 and 8) to process and plot the data.	

Semester- II

Semester: Second Semester	**Course Name:**	Geophysical Fluid Dynamics and Numerical Methods
Course No.: MARO C201	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide deeper understanding of the dynamics of fluid flow in ocean-atmosphere system and the application of numerical methods	*Knowledge on geo-physical fluid dynamics and numerical methods provide the basic background for numerical modelling study of ocean-atmosphere system.*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	**Basic concepts of fluids:** Fluid continuum, Fluid properties, Ideal fluid, Actual fluids, Types of flow; Statics: Pressure surface and body forces on a fluid element; Fundamental equation of fluid statics: Application to compressible and incompressible fluids, Perfect gas equation, Hydrostatic equation.	15
Unit 2	**Kinematics:** Lagrangian and Eulerian methods of description of fluid flow, Stream lines, Streak lines and Trajectories, Steady and non-steady flow, Decomposition of the field of motion in the vicinity of a point, Translation, Rotation, Divergence and deformation, Stream function, Divergence and vorticity, Local and convective derivatives. Dynamics: Equation of continuity and its applications, Non-viscous incompressible flow, Eulerian equations of motion, Inertial and rotational frames of reference, Coriolis force, Irrotational flow, Velocity potential, Integration of the equations of motion, Bernoulli's theorem and its applications	25
Unit 3	Viscous fluids, Coefficient of viscosity, Navier-Stoke's equations of motion for a viscous Newtonian fluid; Laminar flow of viscous incompressible fluids, Reynold's number and dynamic similarity of flows, Physical significance of Reynold's number, Low and high Reynold'snumber. Reynolds stresses and eddy viscosity, Rossby number, Ekman number, Dynamic stability, Circulation and vorticity, Stoke's theorem, Kelvin's theorem, Barotropic and baroclinic fluids, Absolute and relative circulation- Bjerknes circulation theorem and interpretation.	20
Unit 4	**Numerical Methods:** Basic methods of solving equations - Finite difference methods, Interpolation, Spectral methods, Time integration using centred differencing, Implicit time integration and semi implicit time integration. Solution of Algebraic & differential equations: Numerical solution of algebraic	20

	equations, Iteration, Newton-Raphson method. Solution of linear system, Direct method, Gauss elimination method, Matrix - inversion, Eigen value problems, Numerical differentiation and integration. Numerical solution of ordinary differential equation, Iteration method, Picard's method, Euler's method and improved Euler's method. Computational instability	

Suggested Text / References

1. S.W. Yuan (1967): Foundations of FluidMechanics.
2. J. Pedlosky (1987): Geophysical FluidDynamics.
3. G.K. Batchelor (1967): An introduction to FluidMechanics.
4. S.L. Hess (1959): An introduction to TheoreticalMeteorology.
5. Samual A. Elder and J.Williams (1989): Fluid Physics for Oceanographers and Physicists.
6. Benoit Cushman-Roisin and Jean-Marie Beckers (2009): Introduction toGeophysical Fluid Dynamics. Physical and Numerical Aspects.
7. Pedlosky, J. (2013): Geophysical fluid dynamics. Springer Science & Business Media.
8. Chuen-Yen Chow: An introduction to computational Fluid mechanics, John Wiley.
9. Schlichting, Herman: Boundary layer theory. McGraw Hill.
10. Batchelor, G. K. (2000): An introduction to fluid dynamics. Cambridge university press.
11. Currie, I. G. (2012). Fundamental mechanics of fluids. CRC Press.
12. M.K.Jain , S.R.K.Iyengar &R.K.Jain : Numerical methods for scientific and engineering computation. Wiley Eastern Ltd.
13. Krishnamurti, T. N. (2006). An introduction to global spectral modeling. Springer Science & Business Media.
14. Krishnamurti, T. N., & Bounoua, L. (1995): An introduction to numerical weather prediction techniques. CRC press.
15. Washington, W. M., & Parkinson, C. L. (2005): An introduction to three-dimensional climate modeling. University science books.
16. Sorbjan, Z. (1989): Structure of the atmospheric boundary layer.
17. F.Mesinger & A.Arakawa: Numerical methods used in atmospheric models, Vol.1, GARP Publication, Series No.17.

Semester: Second Semester	**Course Name:**	Ocean-Atmosphere Interaction and Ocean Dynamics
Course No.: MARO C202	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide the knowledge on interaction between atmosphere and ocean and forces driving the ocean-atmosphere system	*Students get the knowledge on the fundamental laws of motion in the ocean-atmosphere system and how the coupled system control the weather, climate and bio-geochemistry of the ocean.*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	**Air-sea interaction:** Atmospheric boundary layer- Fluxes of mass, momentum and heat, Wind stress, Wind stress curl, Friction velocity, Eddy viscosity, Reynolds's Number, Turbulence, Scales of air-sea interaction Kolmogorov length scale. Wind profile in the atmospheric boundary layer - mixing length, effect of stability on wind profile, Turbulent transport of fluxes, Von Karman Constant, Atmospheric boundary layer- turbulence closure, mixing length theory, Reynolds stress equation model, Monin-Obhukov length, Monin-Obhukov surface layer similarity theory for stratified atmosphere, Air-sea interaction in coastal zone, Sea and land breeze.	20
Unit 2	Estimation and measurement of fluxes, Fluxes from Satellite observations and ocean weather stations, Heat budget of the ocean, Short wave and long wave heat fluxes, Albedo, Factors affecting short wave and long wave heat fluxes, Sensible and latent heat flux, Net heat flux, Bowen's ratio, Annual cycle of heat fluxes, Spatial and time variation of heat fluxes, Meridional heat transport in the ocean. Convergence and Divergence in Oceans, Upwelling and Sinking, Major upwelling regions of world oceans and Indian Ocean, Meso-scale Eddies and oceanic fronts. Southern Ocean Fronts and Zones-Sea Ice.	20
Unit 3	The basic conservation laws in dynamical oceanography, Dominant forces, Coriolis force, Co-ordinate systems, Types of flows in ocean, Conservation of mass and salt, Barotropic and baroclinic fields, Quasi static conditions, Sigma-t surfaces, Total derivative, Equation of continuity, Stability and double diffusion, Richardson Number, Buoyancy frequency, Bossinesque approximation. The equation of motion, Coriolis force, Gravity and Pressure gradient force. Nonlinear terms, Equation of motion with friction.	15
Unit 4	**Currents without friction:** Inertial motion, Geopotential surfaces, Geostrophic flow, Computation of geostrophic currents, Level of no motion, Advantages and limitations of geostrophic assumption. Relative currents and slope currents. Currents with friction: Equation of motion with friction, Ekman's solution to wind driven flow, Ekman Spiral, Ekman transport, Ekman pumping. Sverdrup's theory of ocean circulation, Mass transport stream function, General form of Sverdrup's equation. Stommel's theory of western boundary currents, Munk's solution for wind driven circulation and Fofonoff's interior transport. Vorticity, Relative, planetary and potential Vorticity, Conservation of potential vorticity and its applications, Westward intensification, Equatorial undercurrent. Ekman pumping, Taylor proudman theorem, Rossby radius of deformation.	25

Suggested Text / References

1. Kraus, E. B. and J. A. Businger Atmosphere - Ocean Interaction, 2ndedition.

2. G.T. Csanady, Air-sea interaction: laws andmechanisms.
3. Y. Toba (2004): Ocean-Atmosphereinteractions.
4. John Marshall and Alan Plumb (2007): Atmosphere, Ocean and climate Dynamics – An introductorytext.
5. Adrian E. Gill (1982): Atmosphere-Ocean Dynamics.
6. Neil Wells, (1986): The atmosphere and Ocean – A physical Introduction.
7. Pond and Pickard, (1983): Introductory DynamicalOceanography.
8. Robert H. Stewart, (2003): Introduction to Physical Oceanography- online edition (public domain).
9. Benoit Cushman-Roisin and Jean-Marie Beckers, (2009): Introduction to Geophysical Fluid Dynamics. Physical and Numerical Aspects.
10. Gill, A. E., (1982): Atmosphere-Ocean Dynamics.
11. John A. Knauss (1997): Introduction to Physical Oceanography.
12. Henk A. Dijkstra (2008): Dynamical Oceanography

Semester: Second Semester	**Course Name:**	Waves, Tides and Storm Surges
Course No.: MARO C203	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide the details about the types of waves in the ocean along with its transformation with bathymetry and the primary reason of the generation of these waves.	*Students learn the difference between tide and wave, their generation mechanisms and their impacts*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	General aspects of ocean waves, wind-waves and swell characteristics, Internal waves, Storm Surges, Tsunamis, Introduction to wind induced surface gravity waves, Ocean wave classification - Capillary and gravity waves, Small amplitude waves- Euler's equation of motion, existence of velocity potential, equation of continuity, Laplace and Bernoulli's equations, derivation of small amplitude wave equation for celerity, length and period. Theories of wave generation- the sheltering theory of Jeffreys, O.M. Phillips and Miles theories. Statistical description of waves and wave breaking, Sea and swell, Linear waves, Wave dispersion, Phase and Group velocity, Wave pressure, Wave energy - potential and kinetic and total energy, energy flux and power. Classification of waves basing on relative depth-shallow and deep water cases for celerity, length, orbital motion of wave particle velocities, accelerations.	20
Unit 2	Finite amplitude wave theories of Airy, Stoke's, Gerstner, Cnoidal and	20

Units	Contents	Hours/ Semester
	Solitary waves, derivation of Stoke's second order waves for wave profile, celerity, particle displacements, surface pressure. Stoke's drift, Formation of Trochiod, Non-linear waves, Shallow water waves, Wave transformations, Shoaling, Refraction and refraction coefficients and their relationship with deep and shallow water wave heights and bathymetry effects of refraction, Diffraction, Reflection, Wave run up, Long-shore currents and rip currents. Orbital motions in deep and shallow water waves, Wave breaking, Wave-height and period distributions, Rayleigh distribution, Wave statistics, Frequency (Energy), Slope and Wave number spectra. Directional wave spectrum.	
Unit 3	Wind and wave Characteristics in the Indian Seas – Deep and Shallow wave characteristics, Seasonal variability of waves: Rough weather period - south-west monsoon, Fair weather period – north-east monsoon, Internal wave variability in Indian Seas, Theory of Internal Waves, Two layer ocean, Normal modes of internal waves, Causes of internal waves, Submarine generated internal waves, Dead water. Planetary Waves, Poincare, Rossby, Kelvin, and Yanai waves, Generation and propagation of Tsunami Waves and Seiches.	20
Unit 4	Introduction to Tides, Tide and Tidal current in the sea, Astronomical and Meteological Tide, Tide producing forces, Lunar and Solar components, Semi-diurnal and Diurnal tides - range differences, Tidal currents and its variability, Internal tides, Spring and Neap tides - Phase and amplitude, Amplitude and cycle time, Tidal Bores, Amphidromic points, Co-tidal lines. Tides in typical ocean regions – Coastal Ocean – Estuaries –Bays - Open Ocean. Newton's law of gravitation – Tidal potential – Harmonic analysis of Tides, Tide generating forces in the ocean, Tide generation theories, Equilibrium theory - Dynamic theory- Observations and Prediction of tides.	20

Suggested Text / References

1. Pond and Pickard, (1983): Introductory DynamicalOceanography.
2. Sverdrup H.U., Johnson M.W. and Fleming R.H. (1958): The Oceans: theirphysics, chemistry and general biology, Prentice Hall Inc., New Jersey.
3. Open University Course team and Butterworth-Heinemann, (1999): Waves, Tidesand Shallow Water Processes; Open University team, 2nd Edition, 1999, Oxford,UK.
4. Philips O. M. (1966): The Dynamics of the upperocean.
5. Pierson W. J., G. Neumann and R. W. James, (1955): Practical methods for observingand forecasting Oceanwaves.
6. B.Kinsman: Wind waves. Prentice-Hall.
7. DEAN, R., & DALRYMPLE, R. (1998). Water wave mechanics for engineers and scientists. Advanced Series on Ocean Engineering. Singapore, New Jersey, Hong Kong: ed.
8. J. William Kamphuis (2000): Introduction to coastal engineering and management, World Scientific Publication.
9. Y.C.Kim: Hand book of coastal and ocean engineering, world scientific publication.

10. H.O. Publication (603): Observing and forecasting of ocean waves, U.S.Department of Navy, 1955.
11. Neumann, G., & Pierson, W. J. (1966): Principles of physical oceanography (Vol. 545), Englewood Cliffs, NJ: Prentice-Hall.
12. Pedlosky, J. (2013): Geophysical fluid dynamics. Springer Science & Business Media.
13. S.Murata et al., Tsunamis, World Scientific Publication.
14. T.S.Murty: Tsunami Waves, World Scientific Publication.

Semester: Second Semester	**Course Name:**	Coastal Oceanography and Estuarine Dynamics
Course No.: MARO C204	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide a basic understanding of various coastal oceanographic processes and their impacts on coast	*Students learn how the coastal processes control the geomorphology of the coast, sediment flow along the coast and the dynamics of estuaries. This knowledge equips them to plan for various coastal protection measures and coastal zone management at regional and global levels.*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	Coastal Geomorphology: Evolution of the coast in relation to sea level changes, Geomorphology of the coast, Shelf geological processes, Beach definition, Beach and surf zone morphology, Coastal land forms, Depositional and Erosional environments, Mud banks, Coastal erosion and accretion, Natural and anthropogenic, Coastal protection methods.	20
Unit 2	Coastal Oceanography: Wave transformations near the coast, Surf Zone, Wave decay in surf zone, Wave breakers, Wave set-up and set-down, Wave run-up on beach face, Infra Gravity waves, Edge waves, Littoral currents, Cross shore and long-shore and rip currents, Cell circulation, Kallakadal- tidal currents, Sediment transport, Aeolian and littoral transport, Classification of coastal sediments.	20
Unit 3	Shoreline Changes, Beaches, Beach Cusps, Edge waves and rhythmic formations, Beach profiles, Profile changes due to storms, Long-shore bars and troughs, Barriers and barrier Islands, Classification of beaches, Beach processes – source, nature and character of the beach material - beach stability, Coastal response to Engineering structures, Shoreline mapping using Remote sensing techniques.	20
Unit 4	Classification of Estuaries: Circulation, Mixing and Stratification, Flocculation, Tidal asymmetry and flushing, Estuarine sedimentation, Tidal	15

Units	Contents	Hours/ Semester
	Prism, Tidal inlets and creeks, Mangroves and Deltas, Intertidal zone, Tidal Flats, Salt marshes, Special features of Chilika and Dhamra Estuary.	

Suggested Text / References

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

Semester: Second Semester	**Course Name:** Practical I	
Course No.: MARO P205	**Credits:** 02	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide hands on training on observation of fundamental oceanographic parameters and their analysis	*Students learn about the techniques and mechanisms of the instruments used for measurements of basic oceanographic parameters and their analysis*	

Course Details

Units	Contents	Hours/ Semester
	Practical session on paper C201 and C202 1. Plotting of vertical sections of temperature, salinity, density and sound speed (measured and estimated) data. Conversion to standard depths. Interpretation of oceanographic features. Preparation of horizontal sections of temperature, salinity and sound speed. Computations of specific volume anomalies and potential temperature using sample data sets. Plotting of T-S diagram and identification of water mass characteristics. Hands on training MATLAB: Signal Analysis, Data interpolation, Time integration using centred differencing, Implicit time integration and semi implicit time integration. Numerical solutions of ordinary differential equations.	

Units	Contents	Hours/ Semester
	2. Oceanographic data collection and Field trips: Spatial and Time-Series stations, Winches, Wire ropes, Messengers, Nansen water bottles, Reversing thermometers, Bucket thermometer for SST, Collection of salinity and oxygen samples, Thermo-salinograph, Autosal and Salinity calibration, Sachi Disk and Radio meter, Mechanical Bathy Thermograph (MBT) and Expendable Bathy Thermograph (XBT), Conductivity, Temperature and Depth (CTD) with Rosette sampler, XCTD. Shipborne hull-mounted ADCP, Argo floats and Gliders for Oceanographic data collection, Towed Oceanographic Data Collection Systems, AUV and AXBT.	

Semester: Second Semester	**Course Name:** Practical II	
Course No.: MARO P206	**Credits:** 02	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide hands on training on observation of waves, tides and their analysis	*Students learn about the techniques and mechanisms of the instruments used for measurements of waves, tides and their analysis*	

Course Details

Units	Contents	Hours/ Semester
	Practical session on paper C203 and C204 1. Wave and Tide Measurements and Data Processing: Bottom mounted pressure sensors, Ship-Borne Wave Recorder (SBWR), Wave-rider Buoys, Directional Wave buoys, Tide Staff and Tide Gauges, Acoustic Tide Gauges, Mooring of Wave buoys and Tide sensors, Coastal and ship-borne Radars for measuring waves. Analysis of sample wave record and estimation of significant wave parameters following Tucker's method. FFT analysis of digital wave data (use FORTRAN) and interpretation. 2. Installation of Automatic Weather Station (AWS), Bathymetry using Echo-sounders, Current measurements in shallow water - Eulerian and Lagrangian methods, Types of Current meters: Propeller and Acoustic Devices, Speed and Direction measurements, Mooring of Current meters, Shallow (<15m) and Deep water (>100m) moorings, Bottom mounted Acoustic Doppler Current Profiler (ADCP).	

Semester: Second Semester	**Course Name:**	Certificate Course on Value Addition of Marine Fishery Product
Course No.: MARO VAC-I	**Credits**: NC	**Core/Elective:** value added
Course Objective:	**Student Learning Outcome**	
To provide provides a platform for the synergy between formal and informal science and technology, institutions and knowledge system.	*Creating technology networks can help students to gain efficiency in preparing value added products from the thrown-away fishes, which in turn shall help in creating a better environment on the beach and nearby. Value addition through research and development is a key focus to train SHGs so that they become entrepreneurs and develop their socio-economic conditions and an alternative livelihood option. Keeping in view the proximity of the university very near to the coast and the available expertise at the Department of Marine Sciences, the course shall help in providing inclusive solutions to the local fishermen and promotes entrepreneurship.*	

Course Details

Units	**Contents**	**Hours/ Semester**
Unit 1	Status of marine fishery resources in the world, India and Odisha. Value addition to marine resources and its reason, Nutritional value of value-added products-in the world, India and Odisha.	NC
Unit 2	Different components of value addition of marine resources- Lime and handicrafts making from sea shell, methods preservation and fish processing for value addition, methods of packaging of value-added marine products, drying and dried fish products, smoking and smoked fish products, different value-added fish products. Export and import potential of value-added marine resources.	NC
Unit 3	Working principles of fish drying machines, Smoking kiln, meat mincer, Vacuum Dryer, Meat Picking Machine, Fish de-boner, Deep Fridge and other accessory instruments. Polymer identification through FTIR Analysis	NC

Semester- III

Semester: Third Semester	**Course Name:**	Advanced Marine Meteorology
Course No.: MARO C301	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide advanced knowledge on meteorology and its application in monsoon, weather analysis and forecasting and boundary layer study	*Students learn about the physics of the atmosphere which control the weather and climate system at the surface and upper levels*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	Physical Meteorology: Thermodynamics of dry and moist air, Thermodynamic diagrams and hydrostatic Equilibrium, Synoptic Meteorology: Air masses and their classification, fronts and frontogenesis. General circulation of the atmosphere, ozone hole and global warming. Synoptic features associated with Indian Monsoon - Onset and withdrawal, Global boundary conditions and their impacts. Predictability of monsoon – active and break cycles.	20
Unit 2	Equations of motion in Cartesian and spherical coordinates, Equation of continuity and their scale analysis. Inertial, geostrophic, gradient,thermal, ageostrophic and cyclostrophic winds. The effect of friction. Comparison of geostrophic and gradient winds. Kinematics of quasi-horizontal motion: Stream lines and trajectories, Relationship between stream lines and trajectories, construction of stream lines and trajectories, Differential properties of the wind field. Blaton's equation and its application for a cyclonic centre. Pressure tendency equation. Dines compensation.	20
Unit 3	Circulation & Vorticity: Kelvin & Bjerknes circulation theorems, its physical interpretation of the terms and its application to land and sea breezes. Vorticity equation and its physical interpretation. Conservation of absolute vorticity and its application. Scale analysis of vorticity equation.	20
Unit 4	Atmospheric turbulence: Reynold's stresses and Reynold's equation of motion. Prandtl's mixing length theory. Wave motion in the atmosphere: Pure Sound waves and internal gravity waves. Surface gravity waves, Rossby waves. Geostrophic adjustment. Barotropic and Baroclinic instability.	20

Suggested Text / References

1. Hess, S. L. (1979): Introduction to theoretical meteorology. RE Krieger Publishing Company.
2. Hewson, E. W., & Longley, R. W. (1944): Meteorology, theoretical and applied(No. QC861 H47). New York: Wiley.
3. Trewartha, G. T., & Horn, L. H. (1954): An introduction to climate (Vol. 1961). New York: McGraw-Hill.
4. Haurwitz, B., & James, M. (1944): Austin, Climatology. McGraw-Hill, New York,191(4), I4.
5. Critchfield, H. J. H. J. (1966): General climatology.
6. S.Peterson, (1941): Introduction to Meteorology. Mcgraw-Hill Book Company, Inc.
7. Petterssen, S. (1956): Weather analysis and forecasting. 2. Weather and weather systems. McGraw-Hill.
8. J.S.Fein & P.L.Stephens: Monsoons, Wiley Inter-science.
9. P.K.Das: Monsoons, NBT Publication.
10. Charney, J. G., & Shukla, J. (1981): Predictability of monsoons. Monsoon dynamics.
11. S.L.Hess: Introduction to theoretical meteorology, Robert E Krieger Publishing Co.
12. Holton, J. R., & Hakim, G. J. (2012). An introduction to dynamic meteorology(Vol. 88). Academic press.
13. S. Panchev: Dynamical Meteorology, D.Reidel Publishing Company.
14. George Haltiner, J., & Frank Martin, L. (1957). Dynamical and physical meteorology.
15. Haltiner,G.J and R.T. Williams: Numerical Prediction and Dynamic Meteorology, Jhon Wiley & Sons.

Semester: Third Semester	**Course Name:**	Remote Sensing and Geographical Information System (GIS) in Marine Sciences
Course No.: MARO C302	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide detail understanding of the application of remote sensing and GIS technique to ocean science	*Students learn the basics of remote sensing, fundamental laws of radiation, GIS and their application in various areas of Marine Sciences along with different sensors and satellites used for remote sensing of the ocean*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	Introduction to Remote Sensing, Principles of aerial photography, Electromagnetic radiation, Solar and terrestrial radiation, Atmospheric effects, Absorption, Transmission and scattering, Spectral response of earth's surface features, Atmospheric windows– concept of signature. Infrared Remote Sensing: Thermal emission, Atmospheric absorption, IR	20

Units	Contents	Hours/ Semester
	sensors, SST retrieval, Atmospheric correction, Effect of cloud, Thermal skin layer, Skin and bulk SST.	
Unit 2	Microwave Remote Sensing: Theory of microwave radiometry, Microwave emission of sea surface, Atmospheric effects, Retrieval of salinity and wind vector, Passive microwave radiometers: SMMR, SSM/I, TRMM/TMI and AMSR, Active microwave radiometers: Microwave interaction with the sea surface, NSCAT, Sea Winds - Altimetry: principles – sea surface height anomaly – ERS, T/P, Jason-1 – observing planetary waves.	20
Unit 3	Applications of AVHRR, Altimeters, SAR - Monitoring of SST, Geostrophic currents, Mesoscale variability, Eddies, Fronts, Upwelling, Sea Ice Satellite capabilities, Global scale coverage, Different types of satellite data products available SeaWiFS, MODIS, OCM-1& 2, SARAL- Altika, TOPEX-Poseidon, ERS - 1 & 2, JASON, QuikScat, etc.	20
Unit 4	Definition of GIS – Components of GIS, Geographical concepts, Input data for GIS, Types of output products, Application of GIS, GIS Data types – Data representation – Data sources – Data acquisition – Geo referencing of GIS data – Spatial data errors – Spatial data structures. Essential Goal of Marine GIS, Spatial Thinking and GIS Analysis in the Marine Context, Conceptual Model of a Marine GIS.	20

Suggested Text / References

1. I.S. Robinson, (1985): Satellite Oceanography- An Introduction for Oceanographersand Remote SensingScientists.
2. Seelye Martin (2014): An Introduction to Ocean Remote Sensing, 2nd Edition, Cambridge Press.
3. Motoyoshi Ikeda and Frederic W. Dobson (1995): Oceanographic Applications of Remote Sensing, CRC Press,USA.
4. Robert H.Stewart, (1985): Methods of SatelliteOceanography.
5. T.D. Allan, (1983): Satellite Microwave RemoteSensing.
6. G.A. Maul, (1985): Introduction to SatelliteOceanography.
7. I. S. Robinson, (2004): Measuring the Oceans from space: The principles and methods of satelliteOceanography.
8. Paul Bolstad, (2019): GIS Fundamentals – A First Text on Geographical Information System, NEW and UPDATED, Sixth Edition. ISBN-13: 978-1593995522.
9. Francis Harvey, (2015): A Primer of GIS, Fundamentals of Geographic and Cartographic Concepts. ISBN-13: 978-1462522187.
10. Karen Steede -Terry, (2000): Integrating GIS and the Global Positioning System. ISBN-13: 978-1879102811.
11. Bradley A. Shellito, (2016): Discovering GIS and ArcGIS. ISBN-13: 978-1319060473.

12. Christian Harder and Clint Brown, (2017): ArcGIS Book. ISBN-13: 978-1589484870.
13. Heather Kennedy, (2006): Introduction to 3D data – Modelling with ArcGIS 3D Analyst and Google Earth. ISBN-13: 978-0470381243.

Semester: Third Semester	**Course Name:**	Ocean Wave and Tide Modelling
Course No.: MARO E303	**Credits:** 04	**Core/Elective:** Elective
Course Objective:	**Student Learning Outcome**	
To provide detail understanding of wave modelling and prediction	*Students learn about different models for wave modelling and use them for prediction of waves accurately and help in disaster management due to storm surge and tsunami*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	Early wave prediction methods, Concept of wave spectrum, Sverdrup-Munk-Bretchneider (SMB) and Pierson-Neumann-James (PNJ) methods of wave prediction.	20
Unit 2	Evolution of 1st, 2nd and 3rd generation wave models, Discrete spectral wave models, Parametric and Hybrid wave models, Coupled discrete wave models, Third Generation Wave Models: 3G-WAM and WAVEWATCH-III.	20
Unit 3	Concept of shallow water wave modelling, Third Generation Wave Model SWAN, Relation to WAM, WAVEWATCH III, General description on SWAN, Physical and Mathematical details, Model Limitations and Applications.	20
Unit 4	Introduction to TSUNAMI early warning system. Basic concepts of Tide Modelling, Introduction to Global Ocean Tide Models- TOPEX/POSEIDON Altimetry.	20

Suggested Text / References

1. SWAMP Group (1985): Ocean Wave Modelling, Plenum Press,(pp.256).
2. M.L. Khandekar: Operational Analysis and Prediction of Ocean Wind Waves, Springer-Verlag,1989.
3. Leo H. Holthuijsen (2010): Waves in Oceanic and CoastalWaters.
4. Stanislaw R. Massel (1996) Ocean Surface Waves: Their Physics andPrediction.
5. G. J. Komen, L. Cavaleri, M. Donelan (1994) Dynamics and Modelling of OceanWaves.
6. James J Obrien (1985) Advanced physical oceanographic numerical modelling (Nano science series).
7. Kantha & Clayson, (2000): Numerical Models of Oceans and Oceanic Processes, Academic Press.
8. Benoit Cushman-Roisin and Jean-Marie Beckers: (2009) Introduction to Geophysical Fluid Dynamics. Physical and Numerical Aspects.

9. P. Muller H. von Storch (2004): Computer Modelling in Atmospheric and Oceanic Sciences.
10. Open source manuals: WAM, WAVEWATCH-III, SWAN and Tide Model - TOPEX/POSEIDON Altimetry.

Semester: Third Semester	**Course Name:**	Marine Geochemistry
Course No.: MARO E304	**Credits:** 04	**Core/Elective:** Elective
Course Objective:	**Student Learning Outcome**	
To provide detail about the geological and chemical processes of the ocean	*Students learn about the concepts of geological and chemical phenomena related to the marine environment and their impacts on biology of the ocean*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	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.	20
Unit 2	Sedimentation: Physicochemical factors in sedimentation, Ionic potential, Hydrogen ion concentration, Redox potential and colloids, Behavior 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.	20
Unit 3	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.	20
Unit 4	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,	20

Units	Contents	Hours/ Semester
	Origin of surface charge, Aggregation of colloids, Role of coagulation in natural waters, Surface phenomena – Langmuir and Freundlich Adsorption isotherms, Trace metal partitioning on solid-solution phases, Particle concentration effects.	

Suggested Text / References

1. Krauskopf, K. B.,(1967): Introduction to geochemistry, Mc.Graw-hill.
2. Goldschmidt, V. M., (1962): Geochemistry, Clarendonpress.
3. Mason, B. and Moore, B., (1956): Principles of geochemistry, John Wiley & Sons,Inc.
4. Riley, J. P. and Skirrow, G., (1975): Chemical oceanography (Vol. 1 & 3), 1975 Academic Press, New York.
5. Krauskopf, K. B. and Bird, (1995): Introduction to geochemistry, Mc-GrawHill.
6. Drever, J. I., (1982): The geochemistry of natural waters, Prentice-Hall, Inc., Englewood Cliffs, N.J.
7. Ocean chemistry and deep sea sediments, (1989): Open University CourseMaterial.
8. Home, R. A., (1969): Marine Chemistry, Reinhold Publishing Corporation, NewYork.
9. Burton, J.D. and Liss, P.S., (1976): Estuarine Chemistry, AcademicPress.
10. Stumm, W. and Morgan, J.J., (1996): Aquatic Chemistry, Wiley- Inter-science, NewYork.
11. Stumm, W., (1987): Aquatic Surface Chemistry, Wiley Inter-science, NewYork.
12. Glasstone, S., (1981): Text Book of Physical Chemistry, Macmillan IndiaPress.
13. Turekian K.K., (2010): Marine Chemistry and Geochemistry, Academicpress.

Semester: Third Semester	**Course Name:**	Environmental Impact Assessment and Management Plans
Course No.: MARO CT300	**Credits:** 04	**Core/Elective:** Elective CBCT
Course Objective:	**Student Learning Outcome**	
To provide knowledge on environmental monitoring and impact assessment.	*Students learn the methods and procedures used in EIA and the legislations on environmental management. This knowledge helps them to prepare EIA reports on various developmental activities including coastal zone development*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	Introduction to Environmental Impact Assessment. Environmental impact Statement and Environmental Management Plan. EIA notifications of Government of India from time to time. Guidelines for	20

Units	Contents	Hours/ Semester
	Environmental audit.	
Unit-2	Environmental Impact Assessment (EIA) Methodologies. Generalized approach to impact Assessment. EIA processes, Scoping EIA methodologies, Procedure for reviewing Environmental impact analysis and statement. Environmental Management Plan and its monitoring, Evaluation of proposed actions.	20
Unit 3	Nexus between development and environment, Socio-economic impacts, Aid to decision making, Formulation of development actions, Sustainable development, categorization of projects under EIA, project planning and implementation, Impact prediction, Mitigation measures.	20
Unit 4	Introduction to. Selection of appropriate procedures, Restoration and rehabilitation technologies. Landuse policy for India. Urban planning for India. Rural planning and landuse pattern. Environmental priorities in India and sustainable development. CRZ notifications and Environmental Impact Assessment in coastal zone. Coastal zone management plans of India.	20

Suggested Text / References

1. W.P. Cunningham, 2010: Principles of Environmental Science.
2. Satsangi and A.Sharma 2015: Environmental Impact Assessment and Disaster Management.
3. R.R.Barthwal 2002: Environmental Impact Assessment.
4. R.Paliwal and L.Srivastava, 2014: Policy Intervention Analysis- Environmental Impact Assessment.
5. C.H.Ecceleston, 2004: Environmental Impact Assessment.
6. J. Hou, 2015: New Urbanism: The future City is Here.
7. James R. Craig, 2010: Earth Resources and the Environment.
8. J. Glassion, 2011: Introduction to Environmental Impact Assessment.
9. Glasson J., Therivel R., Chadwick A, (2005): Introduction to environmental impact assessment Taylor & Francis Group, London and NewYork.
10. Morris P., Therivel R., (2009): Methods of Environmental Impact Assessment 2009, 3rd edition, Routledge, Taylor & Francis Group, London and NewYork.
11. Morris P., Therivel R., (2001): Methods of Environmental Impact Assessment 2001, 2nd edition, Spon Press, Taylor & Francis Group, London and NewYork.

12. Eccleston C. H., (2011): Environmental Impact Assessment 2011, CRC Press, Taylor & FrancisGroup.

Semester: Third Semester	**Course Name:**	Practical I
Course No.: MARO P305	**Credits:** 02	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide hands on training on the instruments used in remote sensing, GIS and models for wave modelling	*Students gets practical training on different wave models, software and tools used in studying remote sensing and GIS.*	

Course Details

Units	Contents	Hours/ Semester
	Practical session on papers C301 and C302 1. Hand on training on WAM, WAVEWATCH-III and SWAN. 2. Retrieval of tidal levels at some selected locations using tools from open sources. 3. Remote Sensing Application for ocean resources: Ocean color and chlorophyll estimation, SST, Bio-optical algorithm, Fishery resources, PFZ forecast & data dissemination. 4. Remote sensing application to marine and coastal environment: Monitoring marine and wetland environment, coastal vegetation, coral reefs, Land use/Land cover study, Environmental Impact Assessment (EIA) studies, CRZ Laws and coastal zone management.	

Semester: Third Semester	**Course Name:**	Practical II
Course No.: MARO P306	**Credits:** 02	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide sea going experience through participation in cruise programmes organized by govt. of India agencies/institutes and to handle various instruments on board	*As a student of Oceanography, a journey into the Ocean and handling of different instruments on board provide satisfaction and all-time experience as an Oceanographer.*	

Units	Contents	Hours/ Semester
	This practical shall be decided depending on the elective courses chosen by the students. **However, a practical session on Data collection onboard research vessels and preparation of Cruise Report can be taken up by the students irrespective of their choice of electives.** 1. Participation in one of the Scientific Missions (Cruise) for data collection(The objective of this exercise is to familiarize the students of Oceanography in field data collection using various scientific equipments) 2. Data processing, analysis and documentation of cruise report (follow standard scientific or departmental research reports of NIO, NIOT, NCCR etc.) using sample data. **Pre-requisites, if any:** Participation in field data collection onboard research vessels to be arranged in advance by contacting national level institutes/organizations. The students are advised to go through the guide – "The Practical Oceanographer – A Guide to Working At-Sea" by Rick Chapman Applied Physics Laboratory (1998), The Johns Hopkins University (158 pages), before they take up this assignment **NOTE:** Students who cannot participate in a cruise onboard ship can demonstrate on field data collection using land based (example Automatic Weather station, CODAR etc.), offshore platform based and/or ship/floating platform based data collection, sample data (Open sources/INCOIS) processing, plotting; and prepare/document a Scientific Mission Report to fulfill the requirement of this practical. Include an appropriate mission plan for the said demonstration, offsite/offline.	

Semester: Third Semester	**Course Name:**	Certificate Course on Marine Litter Monitoring and Management
Course No.: MARO VAC-II	**Credits**: NC	**Core/Elective:** value added
Course Objective:	**Student Learning Outcome**	
To provide knowledge on marine litter pollution.	*Students can learn about the cause and management of marine litter pollution and also about the techniques used in assessing the marine litter pollution*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	**Fundaments on marine litters, status, impacts and transport mechanisms** Marine litter, types of marine litters and their sources, Marine litter-a global problem and present status, marine litter around the world ocean with special reference to Indian Ocean, Impacts of marine litters-marine ecosystem, human health andeconomy. Transport mechanisms of marine litters-different oceanographic and meteorological parameters, riverine transport, transport through ships and tourism and recreation activities.	NC
Unit 2	**Prevention, clean up and legislation** Legislation for prevention of marine litters around the world including India- convention and agreements. Prevention and clean-upof marine litters. Education and awareness on marine litters with special reference to plastics (macro and micro plastics). Plastics in Indian seas and strategy for clean-up of plastic debris, Marine strategy Framework directive (MSFD)- Single use plastics and fishing gear. Methods for measurement of microplastics to reduce releases to the environment, Environmental and health risks of microplastic pollution and its prevention.	NC
Unit 3	**Monitoring of marine litters and laboratory methods for their analysis: Methods for the analysis of mezo, meso, micro plastics in beach samples** • Apparatus and Materials • Beach sediment sample preparation • Segregation of beach litters and their quantification • Density Separation • Determine the mass of Total solids • Wet petroxide oxidation (WPO) • Density Separation of total solids • Use of Microscope for identification • Gravimetric Analysis • Polymer identification through FTIR Analysis	NC

Semester- IV

Semester: Fourth Semester	**Course Name:**	Polar Oceanography and Climate
Course No.: MARO C401	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide knowledge on oceanography of the polar region and its role on climate system	*Students learn about the history of Polar research and contribution of India; natural resources at the pole and their possible extraction methods and above all the role of polar oceans on earth climate system*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	History of polar research and exploration: Past, present and future. Major international polar programs and Indian polar programs. Governance of Antarctic and Artic regions and its protection. Polar natural resources: Anthropogenic demands and impacts. The impact of anthropogenic activities and climate change on the polar oceans. Ozone hole impacts, Pollution in polar ocean, Emerging pollutants, Micro-plastics, SOLAS and MARPOL 73/78.	20
Unit 2	Sea ice, Types, Sea ice properties, Thermodynamics; Sea-ice interactions with atmosphere, ocean; Regional distribution of sea ice (in Artic, Southern Ocean and Antarctica); Gaining and losing Antarctic sea ice variability – Trends and mechanisms; Losing Arctic Sea ice extent; Teleconnections, Polynyas and its importance. Observation methods for Sea ice in polar oceans.	20
Unit 3	Hydrography and circulation of Antarctic and Arctic Oceans: Antarctic circumpolar current, Importance and dynamics Southern Annular Mode, Teleconnections, Impacts and dynamics, Subarctic Seas as a source of Artic change, Variability of Atlantic water inflow to the Northern Seas, Fresh water flux from Northern Seas and Atlantic Meridional Overturning Circulation, Arctic Cyclones.	20
Unit 4	Sea ice in earth system models – Sea ice model mechanics. Applications from satellite platforms. Role of polar oceans on deep ocean circulation and global climate system, Future of Polar Oceanography.	20

Suggested Text / References

1. Farewell to Ice: A report from the Arctic, Peter Wadhams E-book, 2017.

2. A History of Antarctic Science (Studies in Polar Research): G.E. Fogg, Margaret, Thatcher, Cambridge University Press, 2005.
3. Arctic-Subarctic Ocean Fluxes: Defining the Role of the Northern Seas in Climate, Dickson B., Meincke J. & Rhines P., Springer, 2008.
4. Biogeochemical Technologies for Managing Pollution in Polar Ecosystems. Bashkin V., Springer 2016.
5. Climate change in Polar Regions, Turner J. and Marshall G.J., Cambridge University Press, 2011.
6. Introduction to Antarctica. Liggett D., Storey B., Cook Y., Meduna V. (Eds.), Springer, 2015.
7. Introduction to the Physics of the Cryosphere. Melody Sandells and Daniela Flocco, Morgan & Claypool Publishers, 2014.
8. National Research Council. Future Science Opportunities in Antarctica and the Southern Ocean. Washington D.C., The National Academic Press, 2011.http://doi.org/10.17226/13169.
9. Polar Oceans from Space, Josefino Comiso, Springer, 2010.
10. Sea Ice, 3rd Edition, David Thomas, ed., Wiley, 2017.
11. Southern Ocean: Oceanographer's Perspective. Jonath Young, Ice Press, 2015.
12. The New Artic. Evengard B. Larsen J.N. & Paasche, (Eds.), Springer, 2015.
13. The Oceans and Rapid Climate Change. Past, Present and Future. Seidov Dan, Haupt Bernd J., Maslin, Mark A. (Eds.), Geophysical Monograph Series, Wiley and Sons Ltd., 2001.
14. The Technocratic Antarctic, An Ethnography of Scientific Expertise and Environmental Governance. O'Reilly J., Cornell University Press, 2017.
15. http://ncaor.gov.in/antarcticas

Semester: Fourth Semester	**Course Name:**	Marine Biogeochemical Processes
Course No.: MARO C402	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To provide knowledge about marine biogeochemical processes of estuaries and ocean	*Students learn about the concept of nutrient cycle, influence of physical and chemical factors on biogeochemical processes. The course also helps in understanding the impact of climate change on oceanic biogeochemical processes*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	Major ocean biogeochemical cycles: Carbon, Nitrogen, Silicon and Phosphorus cycles, Micro-nutrient dynamics and cycling, Organic matter: dissolved, particulate and colloidal species, sources, classification, composition, distribution, seasonal variations,	15

Units	Contents	Hours/ Semester
	Ecological significance, Growth promoting and growth inhibiting effects, Biogeochemical cycles with special reference to estuaries.	
Unit 2	Phytoplankton and primary productivity, pigments, photosynthesis, Net and gross primary productivity, Rate of primary production in inshore and offshore regions of Arabian Sea and Bay of Bengal, Latitudinal and Seasonal variations in primary productivity, Factors affecting primary production, methods of estimation, Relationship of phytoplankton productivity to light and nutrients, Role of phytoplankton in global carbon cycle, Impacts of climate change, Algal blooms – HABs and TABs- Ocean Colour Monitoring and estimation of primary productivity. Zooplankton communities in estuarine, neritic and oceanic systems. Secondary production- Linkages to higher trophic level, Plankton as indicators of fisheries. Indicator species of water masses. Benthic ecosystem processes, benthic environment and community structure, Organism sediment relations. Benthic pelagic coupling, CDOM.	25
Unit 3	Influence of Physical processes on primary productivity, Hydrodynamic forcing, Upwelling, stratification, mixed layer depth, turbulent mixing, monsoon driven biogeochemical processes in the Arabian Sea and Bay of Bengal, Spatial and Temporal variations in the nutrient concentrations, Response of marine pelagic ecosystems to climatic forcing, OMZ, HNLC, Ocean currents and their impact on marine life, Phytoplankton distribution and patchiness.	20
Unit 4	Plankton in relation to fisheries, Plankton as indicators of fisheries, Potential Fishery Zones, SST variations and pelagic fisheries, Influence of upwelling on oil sardine fishery in Arabian Sea, Larval transport and recruitment, Effects of climate change on Coastal upwelling systems, Fish migrations.	15

Suggested Text / References

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

6. Tom Garrison & Robert Ellis (2013), Oceanography: An invitation to Marine Science (9th Edition Cengage Learning.
7. Frank J. Millero (2013), Chemical Oceanography (4th Edition) by, CRC Press, Taylor & Francis Group.
8. Susan Libes (2009), Introduction to Marine Biogeochemistry (2nd Edition)by, Academic Press.
9. H. Elderfield(2006) The Oceans and Marine Geochemistry (1st Edition)by, Elsevier.
10. Gerry Bearman (2005), Marine biogeochemical cycles (2nd edition) by, The Open University.
11. Thomas S. Bianchi (2007), Biogeochemistry of Estuaries by, Oxford University Press.
12. Horst D. Schulz Matthias Zabel (2006), Marine Geochemistry (2nd edition) by, Springer.
13. Michael E. Q. Pilson (2005), An introduction to the Chemistry of the Sea (2nd Edition) University Press.

Semester: Fourth Semester	**Course Name:**	Numerical Weather Prediction
Course No.: MARO E403	**Credits:** 04	**Core/Elective:** Elective
Course Objective:	**Student Learning Outcome**	
To provide training on numerical modelling, laws governing numerical models, data assimilation and model integration methods and different numerical models	*Students learn details on various numerical models used for forecasting of weather as well as for diagnostic study. Also, they acquire knowledge on various numerical methods and data assimilation techniques.*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	**Introduction**: Overview of numerical weather prediction. Governing equations: continuous equations, map projections, vertical coordinate system, wave oscillations in the atmosphere, filtering approximations.	20
Unit 2	**Numerical methods**: finite-difference methods, time and space differencing, stability analysis; spectral method, spherical harmonics, boundary conditions	20

Unit 3	**Numerical models**: Global models, regional models, mesoscale models. Parameterization of sub-grid scale physical processes: planetary boundary layer, moist microphysics physics, cumulus convection, radiation, air-sea interaction processes, and land surface processes.	20
Unit 4	**Data assimilation**: Objective analysis schemes, continuous data assimilation techniques-3D & 4D Variational assimilation; initialization. Predictability and Ensemble forecasting: Fundamental concept about chaotic systems and atmospheric predictability. Introduction to Weather Research and Forecasting (WRF) Model and hands on experience.	20

Suggested Text / References

1. Tim Vasquez Weather Analysis and Forecasting Handbook, Weather Graphics Technologies.
2. Eugenia Kalnay. Atmospheric modelling, data assimilation and predictability, Cambridge University Press.
3. Patrick Santurette, Christo Georgiev. Weather Analysis and Forecasting: Applying Satellite Water Vapor Imagery and Potential Vorticity Analysis 1st Edition, Academic Press.
4. Jean Coiffier: Fundamentals of Numerical Weather Prediction. Cambridge University Press.
5. George J. Haltiner: Numerical Weather Prediction, Wiley.
6. Lahouari Bounoua and T. N. Krishnamurti: An Introduction to Numerical Weather Prediction Techniques. C R C Press.
7. Peter Lynch: The Emergence of Numerical Weather Prediction.Cambridge University Press.
8. Thomas T. Warner : Numerical Weather and Climate Prediction. Cambridge University Press
9. Haltiner,G.J and R.T. Williams: Numerical Prediction and Dynamic Meteorology Jhon Wiley & Sons.

Semester: Fourth Semester	**Course Name:**	Ocean Circulation Modelling
Course No.: MARO E404	**Credits:** 04	**Core/Elective:** Elective
Course Objective:	**Student Learning Outcome**	
To provide knowledge about modelling ocean circulation	*Student learn about different ocean models and numerical schemes for ocean modelling. Integration of different models with different initial and boundary conditions and analysis of model simulated results equip the students as an ocean modeler*	

Course Details

Units	Contents	Hours/ Semester

Units	Contents	Hours/ Semester
Unit 1	Introduction to Ocean Circulation Modelling: Mechanistic and Simulation models, Conservation of Mass and Momentum – Navier-Stokes equations and Ocean circulation modelling, Spherical coordinates, Conservation of angular momentum, Conservation of Mechanical Energy, Global Ocean Modelling, Hydrostatic Primitive Equations, Initial and Kinematic Boundary conditions, Shallow water equations, Geostrophic adjustment - Quasi-Geostrophy.	20
Unit 2	Numerical Schemes in Ocean Circulation Modelling, Finite Differences-Forward, Backward and Central differences, Explicit and Implicit schemes. Horizontal and vertical grid types, Finite difference and finite element, Lateral boundary conditions, Bathymetry, Model forcing, Model Initialization and Spin up, Ocean data assimilation, Time Differencing and Time Splitting.	20
Unit 3	Barotropic and Reduced gravity models. Basin scale models and Regional models- Cox's Model of Indian Ocean- O'Brien's model of North Pacific Ocean, Holland and Hirschman's Model of Atlantic Ocean.	20
Unit 4	Three-Dimensional Ocean Models, GFDL Modular Ocean Model (MOM), Princeton Ocean Model (POM), ROMS and HYCOM. Hands on experience on HYCOM model.	20

Suggested Text / References

1. D.B. Haidvogel and A. Beckmann, (1999): Numerical Ocean Circulation Modeling (Vol.2), Imperial College Press.
2. James J Obrien, (1985): Advanced physical oceanographic numerical modeling (Nano science series).
3. Pond and Pickard, (2013: Introductory Dynamical Oceanography, Butterworth-Heinemann.
4. Kantha &Clayson, (2000): Numerical Models of Oceans and Oceanic Processes, Academic Press.
5. Benoit Cushman-Roisin and Jean-Marie Beckers, (2009): Introduction to Geophysical Fluid Dynamics. Physical and Numerical Aspects.
6. Muller H. von Storch, (2004): Computer Modelling in Atmospheric and Oceanic Sciences.

Semester: Fourth Semester	**Course Name:**	Marine Pollution
Course No.: MARO E405	**Credits:** 04	**Core/Elective:** Elective
Course Objective:	**Student Learning Outcome**	
To provide knowledge on coastal	*Students learn about the various types of marine pollution,*	

and marine pollution.	*their causes, mitigation and management techniques*

Course Details

Units	Contents	Hours/ Semester
Unit 1	**Introduction** Marine Pollution – definition and types, major pollutants, sources, transport path and dynamics, Anthropogenic impact on estuaries, mangroves, coral beds and interstitial communities, case study of Indian and World Oceans	20
Unit 2	Industrial, agricultural and domestic pollutants, Impact on marine environment and control, Eutrophication and its ecological significance, Plastic pollution and its impact on marine ecosystem, Impact of Mining and dredging to marine biodiversity, Pollution by aquaculture farms, Red tide, Fish kill, Case study. Organic matter pollution, petroleum hydrocarbon pollution, trace metal pollution, nutrient (nitrate, ammonium and phosphate) pollution.	20
Unit 3	**Oil and heavy metal pollution** Composition, source, impact on marine environment and control techniques, success stories on curbing metal pollution **Thermal and radioactive pollution** Thermal pollution – sources, uses of waste heat and ecological impact, Radioactive pollution- sources (natural and artificial), biological effects of radiation, Possible areas in India and case studies of the World Ocean.	20
Unit 4	**Monitoring and management** Environmental monitoring methods for critical pollutants, Biological and ecological indicators of pollution and bio ecological monitoring, Control of marine pollution-legal aspects and international cooperation.	20

Suggested Text / References

1. Clark R.B 1992. Marine pollution 3rd edition Clavendron, Press Oxford.
2. Williams 1996. Introduction to Marine Pollution Control. John Wiley.
3. Michael J. Kennish 1994. Practical Handbook on Estuarine and Marine Pollution.
4. Johnston, R. (ed), 1976. Marine Pollution, Academic Press, London.
5. Goldberg, E. D. 1974. The Health of the oceans, UNESCO Press. Paris.
6. Park, P .K, Kester D.R., J.W. Deudall and B.H Ketchum, 1983. Wastes in the Ocean. Vols. 1 to 3. Wiley Interscience Publishers, New York.

Semester: Fourth Semester	**Course Name:**	Geomorphology and Geodynamics
Course No.: MARO E406	**Credits:** 04	**Core/Elective:** Elective
Course Objective:	**Student Learning Outcome**	
To provide knowledge on application of geomorphology and geodynamics in prediction and resource management	*Students learn about the principles and various concepts of applied geomorphology and geodynamics. Also, they apply their knowledge to sole real time geomorphological and geodynamical issues*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	Nature and scope of Geomorphology, Fundamental concepts- Recent trends in Geomorphology. Approaches to geomorphology- static, dynamic, environmental and applied. Earth movements – Landforms - endogenetic and exogenetic, epirogenic and orogenic, climatic and tectonic factors and rejuvenation of landforms. Dynamics of geomorphology; geomorphic processes and resulting landforms.	20
Unit 2	Basic principles. Concepts of gradation, types of weathering and mass wasting. Concept of erosion cycles. Geomorphology of fluvial tracts, arid zones, coastal regions and glacial regions.	15
Unit 3	Applied Geomorphology: Flood management. Applications of geomorphology in mineral prospecting, Geomorphology of Indian coast with special reference to Odisha.	15
Unit 4	Introduction to geodynamics, Continental Drift: Concept and different lines of evidence. The concept of the Super continent - Gondwanaland and its fragments. Vertical Tectonics: Introduction to Vertical tectonics. Concept of Isostasy.	20

Suggested Text / References

1. Physical Geology - Wm and C Brown - Montgomery, C.W. (1990).
2. An introduction to Coastal Geomorphology - Pethick, J. (1984), Edward Arnold, London, 259p.
3. Process Geomorphology, 5th edition - Ritter, D.F., R.C. Kochel and J.R. Miller (2011). McGraw Hill, NY. Rental text
4. Principles of Geomorphology - Thornbury, W.D. (1969): Wiley Eastern Limited, New Delhi: 594 p.

5. Introduction to Geomorphology - Kale & Gupta (2001). 9. The Evolving Continents - Brain F. Windley (1977), John Wiley & Sons. 385p.
6. Geodynamics Elsevier - Artyushkov E.V. (1983)
7. Introduction to Coastal Processes & Geomorphology: Robin Davidson – Arnott - CUP.
8. Magnetic anomalies over ocean ridges - Vine, F. J., and Matthews, P. M. (1963) Nature, 199, 947-949.
9. The Geology of Continental Margins - Springer Verlag, NY - Burk C. A. & Drake, C. L. (1974).

Semester: Fourth Semester	**Course Name:**	Project/Dissertation
Course No.: MARO P407	**Credits:** 04	**Core/Elective:** Core
Course Objective:	**Student Learning Outcome**	
To train students to carry independent research	*Students learn about the procedure for conducting independent research by designing the study, doing field surveys, sample analysis, data generation and interpretation and also to write research article and thesis*	

Course Details

Units	Contents	Hours/ Semester
Unit 1	Suggested Areas/Topics of the Project – Students are free to select a related and relevant area/topic in Oceanography other than that is proposed below. General Studies (Measurements, Analysis, Data Processing and Database Development etc.): Oceanography, Marine Meteorology, Atmospheric Science, Marine Chemistry/Geochemistry, Marine Biogeochemistry, Marine Geology/Geophysics, Marine Geomorphology. Ocean, Atmosphere and Climate: Special Oceanographic features, Air-Sea interaction processes, Regional Oceanography, Ocean Waves and Tide, Internal Waves in the Ocean, Mud banks, Ocean Circulation, Coastal & Estuarine Circulation, Coastal and Estuarine Oceanography, Littoral Zone Studies, Weather Analysis and Forecasting, Ocean Climate Studies, Climate Change and Polar Science. Ocean Acoustics: Acoustic Modelling, SONAR Performance Modelling (SPM), Ambient Noise Modelling, Modelling of Biological Noise, Reverberation Modelling. Optical Oceanography, Remote Sensing of Oceans, Satellite Oceanography, Marine GIS Ocean Modelling (Global, Regional, Coastal and Local): Wave Modelling, Circulation Modelling, Tide Modelling, Internal wave modelling, Storm Surge Modelling, Coastal Ocean/Hydrodynamic Modelling – Oil Spill,	50

Units	Contents	Hours/ Semester
	Particle Tracking and Ecological Modelling; Agent-Based Modelling (ABM), Sand, Mud and Cohesive Sediment Transport Modelling, Marine Biological Modelling. Coupled Ocean-Atmosphere Modelling, Numerical Weather Prediction and Forecasting, Boundary Layer Modelling, Ocean General Circulation Modelling, Ocean Climate Modelling. Coastal & Ocean Engineering, Coastal and Beach Dynamics, Estuarine Sediment Dynamics, Optimum Tracing of Ship Routes (OTSR), Seabed Microseism. Marine Pollution, Marine Hazards, Coastal Hazards and their Management, Environmental Impact Assessment (EIA), Ocean Resources and Management, Coastal zone Management, Law of the Sea and Coastal Regulation Zone.	
Unit 2	Documentation and minimum two revision of the project report.	30
Total	Two Units	80 hrs.

Semester: Fourth Semester	**Course Name:** Cultural Heritage of South Odisha
Course No.: MARO AC	**Credits**: NC **Core/Elective:** Add-on course
Course Objective: *To familiarizing all the P.G. Students of Berhampur University with the excellent craftsmanship exemplified by the literary stalwarts including Kabi Samrat Upendra Bhanja along with the Arts, Culture and Folk Tradition of South Odisha.*	**Student Learning Outcome** *Students passing out from BU will have knowledge about the history and culture of south Odisha and Kabi Samrat Upendra Bhanja.*

Course Details

Units	Contents	Hours/ Semester
Unit 1 ୟୁନିଟ ୧	Literary works of Kabi Samrat Upendra Bhanja କବିସମ୍ରାଟ ଉପେନ୍ଦ୍ର ଭଞ୍ଜଙ୍କ କୃତି ଓ କୃତିତ୍ୱ	NC

Units	**Contents**	**Hours/ Semester**
Unit 2 ୟୁନିଟ ୨	Other Litterateurs of South Odisha ଦକ୍ଷିଣ ଓଡ଼ିଶାର ଅନ୍ୟାନ୍ୟ ସାରସ୍ୱତ ସାଧକ	NC
Unit 3 ୟୁନିଟ ୩	Cultural Heritage of South Odisha ଦକ୍ଷିଣ ଓଡ଼ିଶାର ସାସ୍କୃତିକ ବିଭବ	NC
Unit 4 ୟୁନିଟ ୪	Folk and Tribal Traditions of South Odisha ଦକ୍ଷିଣ ଓଡ଼ିଶାର ଆଦିବାସୀ ଓ ଲୋକ ପରମ୍ପରା	NC

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