# Postgraduate Program in Ocean Engineering

# 1. Preamble

Bangladesh has made significant advancements in establishing its maritime boundaries in recent years, notably through the International Tribunal for the Law of the Sea (ITLOS) ruling on March 14, 2012. This ruling extended Bangladesh's maritime zone by awarding an additional 111,000 square kilometres of the Bay of Bengal. This expansion unfolds unprecedented opportunities for resource exploration and sustainable development. Bangladesh, being a riverine nation, connects hundreds of rivers downstream to the Bay of Bengal, and this unique feature provides flourishing opportunities for harnessing resources from the sea and distributing them throughout the country. Also, it allows a growing prospect for the blue economy, which can further develop Bangladesh.

However, despite the considerable increase in maritime territory, exploration activities within this new zone have been minimal. The Technical Services Group (TSG) has conducted only one survey in the past 12 years, with no substantial follow-up exploration efforts. This limited activity highlights a critical gap in the comprehensive exploration and management of the newly acquired maritime area.

In the global context, the Ocean Decade, initiated as the United Nations Decade of Ocean Science for Sustainable Development (2021-2030), emphasizes the urgent need for innovative ocean science to address challenges like climate change, marine pollution, and biodiversity loss. Achieving the vision of "the science we need for the ocean we want" requires scientific knowledge and skilled human resources with expertise in Ocean Engineering.

To address these gaps, the Department of Naval Architecture and Marine Engineering (NAME) at Bangladesh University of Engineering and Technology (BUET) proposes the introduction of a Master of Science (M.Sc.)/ Master of Engineering (M.Engg.) program in Ocean Engineering. This program aims to bridge the advanced maritime research and resource management gap by providing specialized education and training in critical areas essential for effectively utilizing Bangladesh's expanded maritime domain.

The M.Sc./M.Engg. program in Ocean Engineering will encompass various topics, including hydrodynamics, coastal and offshore engineering, marine renewable energy, oceanography, and maritime safety. The curriculum is

designed to enhance survey techniques, improve the accuracy and efficiency of maritime surveys, and advance exploration technologies. By focusing on sustainable resource management, the program will support responsible use of marine resources and bolster national security through improved maritime capabilities.

Integrating Ocean Engineering into the Naval Architecture and Marine Engineering (NAME) program is crucial for a holistic understanding of marine systems. Ocean Engineering addresses the study of oceanic environments and the design of systems operating within them, complementing and enhancing the curriculum of naval architecture. This integration promotes advanced research in underwater robotics, marine renewable energy, and offshore engineering, addressing complex maritime expansion and sustainability challenges.

Moreover, the program will integrate contemporary advancements associated with the fourth industrial revolution (IR 4.0), such as autonomous ship technology, the Internet of Things (IoT), and data analytics. These technologies are pivotal for modern maritime engineering and will be covered in the program to ensure that graduates are equipped with the latest knowledge and skills to tackle current and future challenges in maritime engineering.

Additionally, the program will contribute to developing marine renewable energy technologies, address maritime safety and security protocols, and promote research into the physical aspects of oceanography, marine geophysics, and advanced marine hydrodynamics. By fostering expertise in these areas, BUET aims to support the sustainable development of Bangladesh's maritime resources and enhance its position as a leader in ocean engineering research and technology.

The curriculum of B.Sc. and M.Sc./M.Engg. in NAME primarily focuses on marine infrastructures, including their design, production, hydrodynamics, and structure. Incorporating Ocean Engineering into the NAME program enriches the curriculum and aligns with industry needs and global challenges. It provides graduates with a competitive edge and prepares them to contribute effectively to both the advancement of maritime technology and the sustainable management of ocean resources.

The M.Sc./M.Engg. program in Ocean Engineering at BUET will be crucial in addressing the existing exploration gaps, advancing maritime technology, and

preparing the next generation of engineers to effectively manage and utilize Bangladesh's expanded maritime zone. This initiative aligns with BUET's commitment to excellence in education and research and supports the nation's strategic goals in marine resource management and technological advancement.

## 2. Admission Requirements

For admission to the courses leading to the degree of M.Sc. Engg./M. Engg. (OCE), an applicant must have either a bachelor's degree in Naval Architecture and Marine Engineering/ Mechanical Engineering/ Civil Engineering/ Water Resource Engineering/ Offshore Engineering/ Coastal Engineering or in the relevant engineering field, having a minimum GPA of 2.50 out of 4.00 or its equivalent from any recognized university.

## 3. Rules and Regulations

For all post graduate degrees in Engineering, Architecture, Urban and Regional Planning and Physics, Chemistry and Mathematics, in addition to test, assignments and/or examinations during the semester may be given by the teacher(s) concerned, there shall be a written examination and/or other test for each of the subjects offered in a semester at the end of that semester. The dates of which shall be announced by the Dean of the respective faculties at least two weeks before the commencement of the examination. The final grade in a subject shall be based on the performance in all tests, assignments and/or examinations.

## 3.1 Grading System

Final grades for courses shall be recorded as follows:

| Grade | Merit Description | Grade Points | Numerical Markings |
|---|---|---|---|
| A (Plus) | Excellent | 4.0 | 90% and above |
| A | Very good | 3.5 | 80% to below 90% |
| B (Plus) | Good | 3.0 | 70% to below 80% |
| B | Average | 2.5 | 60% to below 70% |
| C | Pass | 2.0 | 50% to below 60% |
| F | Failure | 0 | Below 50% |
| I | Incomplete | - | |
| S | Satisfactory | - | |
| U | Unsatisfactory | - | |
| W | Withdrawn | - | |

**Note:**

- Courses in which the student gets F grades shall not be counted towards credit hour requirements and for the calculation of Grade Point Average (GPA).
- Grade I is given only a student is unable to sit for the examination of a course at the end of the semester because of circumstances beyond his/her control. He/she must apply to the Head of the Department within one week after the examination to get an I grade in that course. It must be completed within the next two semesters, otherwise, the I grade becomes an F grade. He/she may, however, be allowed to register without further payment of tuition fees for that course.
- Satisfactory or Unsatisfactory- used only as final grades for thesis/project and non-credit courses. Grade for thesis/project "In Progress" shall be so recorded. If, however, thesis/project is discontinued an I grade shall be recorded.

## 3.2 Qualifying Requirements

The qualifying requirement for graduation is that a student must earn a minimum grade point of 2.65 based on the weighted average in his course work.

A student obtaining F grade in a course may be allowed to repeat the course with the prior approval of Head of the Department on the recommendation of the Supervisor/Advisor. Such approval shall be reported to the BPGS.

A student shall not be allowed to continue the program if he/she obtains a total of three or more F grades in one or more than one subjects taken together, during the course of his/her studies.

If at the end of the second or any subsequent semester, the cumulative GPA falls below 2.5, he/she shall not be allowed to continue in the program.

## 3.3 Course Work

For the M.Sc. Engineering program in Ocean Engineering, students are required to complete at least four (04) courses within the Ocean Engineering curriculum. The remaining courses must be selected from the Naval Architecture and Marine Engineering curriculum.

For the Master of Engineering program in Ocean Engineering, students are required to complete at least six (06) courses within the Ocean Engineering curriculum. The remaining courses must be chosen from the Naval Architecture and Marine Engineering curriculum.

## 3.4 Thesis/Project

In addition to successful completion of course works every student shall submit a thesis on his/her research work or a report on his/her project work, fulfilling the requirements as detailed below.

Every student submitting a thesis/project in partial fulfillment of the requirements of a degree, shall be required to appear at an oral examination, on a date or dates fixed by the Supervisor concerned in consultation with the Head of the Department and must satisfy the examiners that he/she is capable

of intelligently applying the results of this research to the solution of problems, of undertaking independent work, and also afford evidence of satisfactory knowledge related to the theory and technique used in his/her research work.

## 4. Summary of Postgraduate Courses

| Course No | Subject Title | Credit Hours |
|---|---|---|
| OCE 6000 | Thesis | M.Sc. Engg.: 18 |
| OCE 6002 | Project | M. Engg.: 6 |
| OCE 6101 | Marine Materials and Corrosion | 3 |
| OCE 6102 | Fracture and Fatigue | 3 |
| OCE 6103: | Design of Ocean Structures | 3 |
| OCE 6201: | Elements of Ocean Engineering | 3 |
| OCE 6202: | Ocean Waves and Tides | 3 |
| OCE 6203: | Fundamentals of Subsea Engineering | 3 |
| OCE 6301: | Physical Oceanography | 3 |
| OCE 6302: | Hydroacoustics | 3 |
| OCE 6401: | Marine Sustainability and Environmental Impact Assessment | 3 |
| OCE 6402: | Maritime Policies | 3 |
| OCE 6403: | Blue Economy | 3 |
| OCE 6501: | Oceanic Remote Sensing | 3 |
| OCE 6502: | Integrated Seabed Mapping Systems | 3 |
| OCE 6503: | Marine Geophysics | 3 |
| OCE 6601: | Mathematical Methods in Ocean Engineering | 3 |

| Course No | Subject Title | Credit Hours |
|---|---|---|
| OCE 6602: | Numerical Methods in Ocean Engineering | 3 |
| NAME 6103 | Advanced Finite Element Method for Ship Structures | 3 |
| NAME 6206 | Advanced Computational Fluid Dynamics | 3 |
| NAME 6207 | Turbulence Modeling | 3 |
| NAME 6301 | Analysis and Design of Welded Structures | 3 |
| NAME 6404 | Risk Analysis of Maritime Transport | 3 |
| NAME 6405 | Artificial Intelligence for Marine Engineering | 3 |
| NAME 6406 | Advanced Maritime Economics | 3 |
| NAME 6407 | Buoy Engineering | 3 |
| NAME 6505 | Marine Renewable Energy | 3 |
| NAME 6508 | Measurement and Data Analysis | 3 |
| NAME 6601 | Mechanics of Water Waves | 3 |
| NAME 6604 | Hydrodynamic Loading of Floating Bodies | 3 |
| OCE 6700 | Ocean Engineering Seminar | 0 |
| OCE 6701 | Field Visit/ Survey | 0 |

## 5. Detailed Syllabus of Postgraduate Courses

**OCE 6101: Marine Materials and Corrosion**

3.00 Credit, 3 hrs./wk.
Course Content:

Materials Science/Engineering-Marine environment perspective. Principles of materials selection and failure prevention. Principles of materials deterioration/corrosion. Corrosion zones. Corrosion variables. Forms of corrosion. Specific engineering materials related to marine structures. Corrosion control and prevention. Corrosion of steel embedded in marine structures prepared with concrete and its prevention. Fracture and fracture control.

Reference Book:

- Corrosion and Corrosion Control R. Winston Revie, Herbert H. Uhlig, 4th Edition, 2008.
- Corrosion Engineering by M. Fontana, 3rd Edition, 2005.
- Principles and Prevention of Corrosion by D. Jones, 2nd Edition, 1992.

**OCE 6102: Fracture and Fatigue**

3.00 Credit, 3 hrs./wk.
Course Content:

Overview of structural reliability in presence of cracks under static and cyclic loading. Griffith criterion, linear elastic fracture mechanics, elastoplastic fracture mechanics, stress intensity factor, energy release rate, international standards for testing and assessment of fracture and fatigue, control of fracture and fatigue.

Reference Book:

- Elements of Fracture Mechanics by Prasant Kumar, 2014.
- Fracture Mechanics: Fundamentals and Applications by T. L. Anderson, 3rd edition, 2004.

- Fracture and Fatigue Control in Structures: Applications of Fracture Mechanics by John M. Barsom and Stanley T. Rolfe, 3rd edition, 1999.
- Practical Fracture Mechanics in Design by Arun Shukla, 2nd edition, 2004.

**OCE 6103: Design of Ocean Structures**

3.00 Credit, 3 hrs./wk.
Course Content:

Concepts related to foundational information necessary for the design of ocean structures. Fundamental concepts of floating body, fixed body and moored line hydrostatics; wave forces on small and large bodies; dynamic response of floating bodies; pile and gravity foundation geotechnics.

Reference Book:

- Ocean structures: Construction, materials, and operations by Srinivasan Chandrasekaran, and Arvind Jain, Crc Press, 2017.
- Wave forces on offshore structures by Sarpkaya, T. Cambridge university press, 2014.
- Essentials of offshore structures: framed and gravity platforms by D.V. Reddy, A. S. J. Swamidas, CRC press, 2013.
- Floating structures: a guide for design and analysis by Barltrop, N. D. P., 1998
- Marine structural design by Yong Bai, and Wei-Liang Jin, Elsevier, 2003.

**OCE 6201: Elements of Ocean Engineering**

3.00 Credit, 3 hrs./wk.
Course Content:

An overview of ocean engineering. The ocean environment. Coastal and offshore structures. Materials and corrosion in ocean environment. Underwater systems. Underwater acoustics. Instrumentation for Ocean application. Physical modelling. Safety and environmental regulations and ethics. Ocean engineering design.

Reference Book:

- Elements of Ocean Engineering by Robert E. Randall, SNAME, 2010.
- Handbook of Ocean Engineering by Manhar R. Dhanak and Nikolaos I. Xiros, Springer, 2016.

**OCE 6202: Ocean Waves and Tides**

3.00 Credit, 3 hrs./wk.
Course Content:

Small amplitude linear wave theory, standing and propagating waves, wave energy, refraction, diffraction, transformation in shallow water, statistics of random seas, spectral energy density, generating eave time series using the random phase methods forces on structures, nonlinear effects. Description of tides as long waves, equilibrium tide, mathematical modeling including friction, nonlinear effects, and Coriolis forces, tidal analysis.

Reference Book:

- Water Wave Mechanics for Engineers and Scientists by Robert G. Dean, and Robert A. Dalrymple, 1st edition, 1984.
- Tides, Surges and Mean Sea-Level by David T. Pugh, John Wiley and Sons, 1996.
- Tidal Analysis and Prediction by Bruce B. Parker, 2007.

**OCE 6203: Fundamentals of Subsea Engineering**

3.00 Credit, 3 hrs./wk.
Course Content:

Orientation to subsea engineering fundamentals; includes SURF (Subsea, Umbilicals/Controls, Risers, Flowlines) equipment and configurations; exposure to practical, industry focused problems; subsea equipment components; design considerations and design drivers; subsea production operations; integrity critical maintenance activities; renewables.

Reference Book:

- Subsea Engineering Handbook by Yong Bai and Qiang Bai, 2nd Edition, Gulf Professional Publishing, ISBN 9780128126226, 2019.
- Introduction to Petroleum Engineering by John Fanchi and Richard Christiansen, John Wiley and Sons, ISBN-13: 978-1119193449, 2017.

**OCE 6301: Physical Oceanography**

3.00 Credit, 3 hrs./wk.
Course Content:
Introduction, descriptive vs. dynamic approach. Geometry and dimensions of oceans and ocean floor. Physical laws and governing equations of ocean flows. Properties of sea water. Inertia current. Geostrophic (barotropic and baroclinic) currents. Wind-driven current. Conservation of vorticity; westward intensification of currents. Small and finite-amplitude surface waves. Internal waves. Long waves. Other topics such as hurricanes, Gulf Stream, ENSO.

Reference Book:

- Descriptive Physical Oceanography by George L. Pickard, and William J. Emery, 5th Edition, 1990.
- Ocean Circulation by Open University staff, 2nd Edition, 2001.
- Essentials of Oceanography by Trujillo and Thurman, 10th Edition, 2011.

**OCE 6302: Hydroacoustics**

3.00 Credit, 3 hrs./wk.
Course Content:

The theoretical study of the fundamental relations of energy transmission in the ocean. Detailed coverage of components of stress, strain and motion, waves of finite amplitude, ray characteristics, refraction of dispersive wave train, boundary conditions, ray solutions and surface image solutions.

Reference Book:

- Applied Underwater Acoustics by Leif Bjørnø, Elsevier, 2017.

- Underwater Acoustics: Analysis, Design and Performance of Sonar by Richard P. Hodges, Wiley, 2010.
- Fundamentals of Underwater Acoustics by Orlando Camargo Rodríguez, Springer, 2023.

**OCE 6401: Marine Sustainability and Environmental Impact Assessment**

3.00 Credit, 3 hrs./wk.
Course Content:

Environmental impacts related to anthropic activities, sustainability concept, environmental impact assessment procedures, environmental certification protocols, sustainable development goals of United Nations, environmental footprint such as carbon and water footprint, Life Cycle Analysis (LCA), marine renewable energy sources and sustainable transport, and the related energy, environmental and economic effects, case studies for marine and coastal applications.

Reference Book:

- Ocean sustainability in the 21st century by Arico, and Salvatore, Cambridge University Press, 2015.
- Sustainability in the maritime domain: towards ocean governance and beyond by Angela Carpenter, Tafsir M. Johansson, and Jon A. Skinner, Springer Nature, 2021.
- Environmental Impact Assessment: Incorporating Sustainability Principles by Tor Hundloe. Springer Nature, 2022.

**OCE 6402: Maritime Policies**

3.00 Credit, 3 hrs./wk.
Course Content:

International regulatory perspectives related to the maritime industry; safety, security and international seaborne trade aspects of the shipping industry; Political and economic dimensions and motivations of UN, IMO and EU regulatory frameworks; Law relating to “wet shipping” operations, Blue carbon- coasts and climate change, impacts and adaptation, Trade of

commercially-exploited species under the Convention for the International Trade of Endangered Species of Wild Fauna and Flora (CITES).

Reference Book:

- Maritime Governance and Policy-Making by Michael Roe, Springer, 2012.
- Maritime human factors and IMO policy by Jens-Uwe Schröder-Hinrichs, Erik Hollnagel, Michael Baldauf, Sarah Hofmann, and Aditi Kataria, 2013.
- International law and ocean use management: The evolution of ocean governance (Ocean management and policy series) by Lawrence Juda, 1996.
- Ocean governance: Strategies and approaches for the 21st century by Honolulu, and Thomas A. Mensah, 1996.

**OCE 6403: Blue Economy**

3.00 Credit, 3 hrs./wk.
Course Content:

Principles of the blue economy, The role of the ocean in global economic and social systems, Principles of sustainability and their application to the blue economy, National blue economy sectors and strategies, Blue economy stakeholders, Blue economy innovations, The fundamental techniques used to value natural resources and ecosystem services/Economic Valuation of Marine Resources, Biodiversity conservation and Climate resilience in the blue economy, Renewable Energy from Marine Resources, Case studies from different sectors of the blue economy.

Reference Book:

- Maritime Economics by Martin Stopford, 3rd Edition, 2009.
- Successful Blue Economy Examples with an Emphasis on International Perspectives by
  Frontiers in Marine Science, Volume 6, 2019.

- Towards defining the Blue Economy: practical lessons from Pacific Ocean governance by Keen, M. R., Schwarz, A.-M., and Wini-Simeon, L., 2018.
- The mechanics of blue growth: management of oceanic natural resource use with multiple, interacting sectors by Klinger, D., Eikeset, B., Davíðsdóttir, A., Winter, M., and Watson, J., 2018.
- The Blue Economy and the United Nations' sustainable development goals: Challenges and opportunities by Lee, K.-H., Noh, J., Khim, J. S., Volume 137, Environment International, 2020.
- Blue Economy and Resilient Development: Natural Resources, Shipping, People, and Environment by Tianming Gao, Vasilii Erokhin, Konstantin Zaikov, Andrei Jean Vasile, and Jonel Subić, MDPI, 2022.

**OCE 6501: Oceanic Remote Sensing**

3.00 Credit, 3 hrs./wk.
Course Content:

Radiative processes, remote sensors and sensor platforms. Photogrammetry, radiometry and multispectral pattern recognition. Image interpretation, data processing and applications. Ocean research examples from aircraft and spacecraft.

Reference Book:

- Remote Sensing of Ocean and Coastal Environments by M. Rani, S. Rehman, H. Sajjad, K. Seenipandi, and P. Kumar, 2020.
- An Introduction to Ocean Remote Sensing by S. Martin, 2nd Edition, Cambridge University Press, 2014.
- Photogrammetry-Remote Sensing and Geoinformation by M. A. Lazaridou, and E. N. Patmios, 2012.
- Discovering the Ocean from Space by I. S. Robinson, 2010.
- Metrology for Remote Sensing Radiometry by B.C. Johnson, S.W. Brown, and J.P. Rice, 2004.

**OCE 6502: Integrated Seabed Mapping Systems**

3.00 Credit, 3 hrs./wk.
Course Content:

Overview of typical applications that involve mapping the sediment-water interface in the ocean and adjacent waters. Emphasis on defining the task-specific resolution and accuracy requirements. Fundamentals of acoustics relevant to seabed mapping. Progressions through typical configurations involving single beam, sidescan, phase differing and multibeam systems. Integration of asynchronous 3D position, orientation and sound speed measurements with sonar-relative acoustic travel times and angles. Analysis of impact offsets, misalignments and latency in all integrated sensors. Fundamentals of seismic imaging for subsurface characterization.

Reference Book:

- Seafloor Mapping along Continental Shelves: Research and Techniques for Visualizing Benthic Environments by Charles W. Finkl and Christopher Makowski, 2016.
- The Sea Floor: An Introduction to Marine Geology by Eugen Seibold, and Wolfgang Berger, 4th Edition, 2018.
- Underwater Acoustics: Analysis, Design and Performance of Sonar by Richard P. Hodges, 2011.

**OCE 6503: Marine Geophysics**

3.00 Credit, 3 hrs./wk.
Course Content:

Plate tectonics, earthquake and faulting, geodynamics, ocean ridges and transform faults, hydrothermal vents, trenches and oceanic islands, subduction zones, accretionary and erosion wedges, structure and evolution of ocean basins, sedimentary basins and continental rifts, exploration of the oceans using geophysical methods.

Reference Book:

- Marine Geophysics, by E.J.W Jones, Wiley, 1999.

- The Ocean Basins: Their Structure and Evolution, 2nd Edition, The Open University Oceanography, 1998.
- The Solid Earth, by C. M. R. Fowler, 2nd Edition, Cambridge University Press, 2004.
- Geodynamics by Turcotte, Donald L., Schubert, and Gerald, 3rd Edition, Cambridge University Press, 2014.

**OCE 6601: Mathematical Methods in Ocean Engineering**

3.00 Credit, 3 hrs./wk.
Course Content:

Formulation of physical problems: Vibrations of a taut string and an elastic rod; Diffusion, shallow water waves and other problems. Partial differential equations: Review of PDEs, the Laplace, wave and heat equations. Separation of variables. Eigenvalue problems. Fourier series, Fourier and Laplace Transforms: Use of transforms in solving ODEs and PDEs. Green's functions: Application to bending of an elastic beam and other problems. Bessel and Hankel functions: Wave radiation from a circular cylinder. Complex Analysis: Functions of a complex variable, complex integral calculus, Taylor series, Laurent series and the Residue Theorem. Complex potential.

Reference Book:

- Mathematical Analysis in Engineering by C. C. Mei, Cambridge University Press, 1997.
- Advanced Mathematical Methods for Engineering and Science Students by G. Stephenson, and P. M. Radmore, Cambridge University Press, 1990.
- Fundamentals of Mathematical Physics by Edgar A. Kraut, 2007.
- Introduction to Applied Mathematics by Gilbert Strang, Wellesley-Cambridge. Press, 1986.

**OCE 6602: Numerical Methods in Ocean Engineering**

3.00 Credit, 3 hrs./wk.
Course Content:

Numerical error analysis; Consistency, stability and convergence of numerical methods; Numerical methods for boundary value problems: shooting, parallel shooting and finite difference methods for linear and nonlinear problems; Numerical methods for matrix eigenvalue problems: power method and its variants; Iterative methods for solving linear systems: Jacobi, Gauss-Seidel and SOR methods; Numerical methods for initial value problems: Euler, Taylor, Runge-Kutta, multistep, predictor-corrector methods; Nonlinear systems and optimization: Newton's method for nonlinear systems, unconstrained optimization, and constrained optimization; Fourier transform: Discrete Fourier Transform (DFT) and trigonometric interpolation, and the fast Fourier transform. Differential Equations (Special Emphasis: Special Functions, Green's functions), Integral Transforms, Singular Integral Equations.

Reference Book:


- Numerical Methods using MATLAB by J.H. Mathews and K.D. Fink, Prentice-Hall, 1999.
- Numerical methods for scientific and Engineering computations by M.K. Jain, S.R.K.I. Yengar, R.K. Jain, New Age International (P), Ltd., 1999.
- Numerical Methods by W. Bohem and H. Prautzsch, 1993.
- Theory and Applications of Numerical Analysis by Philips, G. M., Taylor, P. J., 2nd Edition, Academic Press, 1996.
- Applied Numerical Methods by Gourdin, A. and M Boumhrat, Prentice Hall India, New Delhi, 2000.
- Numerical Methods for Engineers by Gupta, S. K., Wiley Eastern, New Delhi, 1995.
- Advanced Numerical Analysis by Prof. P.P. Gupta, G.S. Malik, and J.P. Chauhan, 2020.
- Numerical Methods for Engineers by Steven C. Chapra Berger, Raymond P. Canale, 7th edition, McGraw Hill, 2014

**OCE 6700: Ocean Engineering Seminar**

Mandatory registration to a non-credit (satisfactory/unsatisfactory) course in each semester until approval of thesis/project proposal.

**OCE 6701: Field Visit/Survey**

Mandatory enrollment in a non-credit (satisfactory/unsatisfactory) course that includes at least one week of field visits or surveys.

**NAME 6103: Advanced Finite Element Method for Ship Structures**

3.00 Credit, 3 hrs./wk.
Course Content:

Isoparametric elements, plate, and shell elements. Vibration frequency analysis of ship structures. Linear dynamic response analysis of ship structures. Nonlinear analysis in solid and structural mechanics, geometric nonlinearities, nonlinear material behavior. Pre- and post-processing, use of computer graphics in analysis.

Reference Book:

- Non-linear finite element analysis in structural mechanics by Wilhelm Rust, Springer, 2015.
- Structural analysis with the finite element method, Linear statics, Beams, plates and shells by Eugenio Onate, Vol. 2, Springer, 2013.
- Finite element analysis of solids and structures by Sudip S. Bhattacharjee, CRC Press, 2021.
- The finite element method in engineering by S.S. Rao, Elsevier, 2011.

**NAME 6206: Advanced Computational Fluid Dynamics**

3.00 Credit, 3 hrs./wk.
Course Content:

Potential flow: Vorticity and circulation, Kelvin's theorem, Biot-Savart law, velocity induced by a straight vortex segment, statement of the potential flow problem, general solution based on Green's identity, basic solution based on source, sink, doublet and vortex.

Flow over three-dimensional wings: Definition of the problem, separation of the thickness and the lifting problem, symmetric wing with non-zero thickness at zero angle of attack, zero thickness cambered wing at angle of attack-lifting surfaces, the aerodynamic loads.

Perturbation methods: Thin airfoil problem, second order solution, leading edge solution, matched asymptotic expansions, lifting line model, slender wing theory, slender body theory.

Boundary element method: Basic formulation, reduction of the problem to a set of linear algebraic equations, lower and higher order singularity elements, influence coefficients and solutions using Neumann and Dirichlet boundary conditions, lifting line solution by horseshoe elements, lifting surface solution by vortex ring elements.

Statement of the ship-wave problem: Rankine source panel method, finite volume method and RANS equations, Virtual towing tank.

Reference Book:

- Computational Fluid Mechanics and Heat Transfer by John C. Tannehill, Dale A. Anderson and Richard H. Pletcher, 2nd Edition, 1997.
- Computational Fluid Dynamics, Volume II by Klaus A. Hoffmann and Steve T. Chiang, 4th Edition, 2000.
- Computational Fluid Dynamics by T. J. *Chung*, 2002.
- Essential Computational Fluid Dynamics by Oleg Zikanov, 2010.

**NAME 6207: Turbulence Modeling**

3.00 Credit, 3 hrs./wk.
Course Content:

Introduction to turbulent flows: Governing equations for turbulent flows: Decomposition and averaging of instantaneous quantities; Velocity correlations. Reynolds-averaged Navier-Stokes (RANS) equations, Turbulent kinetic energy equation, Dissipation rate equation. Scalar transport equation: Zero equation models: Algebraic models: eddy viscosity and mixing length hypothesis; Cebeci-Smith and Baldwin-Lomax models, one- and two-

equation models; low-Reynolds number effects, effects of compressibility; Reynolds stress transport equations; Second-order closure models: Reynolds-stress and algebraic stress models: Introduction to large-eddy Simulation (LES). Detached-eddy simulation (DES) and direct numerical simulation (DNS).

Reference Book:

- Computational Fluid Dynamics, Volume III by Klaus A. Hoffmann and Steve T. Chiang, 4th Edition, 2000.
- Analysis of Turbulent Flows with Computer Programs by Tuncer Cebeci, 3rd Edition, 2013.
- Turbulent Flow by R.J. Garde, 3rd Edition, 2009.
- Fundamentals of Turbulence Modelling by Ching-Jen Chen and Shenq-Yuh Jaw, 1997.

**NAME 6301: Analysis and Design of Welded Structures**

3.00 Credit, 3 hrs./wk.
Course Content:

Residual stresses in welded joints; Distortion in weldments; Fracture toughness; Brittle and fatigue fracture of welded structure; Effects of distortion and residual stress on buckling strength of welded structures; Welded cracking and joint restraint. Effects of weld defects on service behaviors; Nondestructive testing of welded joints.

Strength of welded structures; Design of welded connections; miscellaneous structural design; Joint design and production for static and dynamic welded structures.

Reference Book:

- Welding Principles and Applications by Larry Jeffus, Cengage Learning, 8th Edition, 2017.
- Fracture Mechanics: An Introduction by E. E. Gdoutos, Springer Publication, 2nd Edition, 2005.
- Design of Welded Structures by Omer W. Blodgett, The James F. Lincoln Arc Welding Foundation, 1st Edition, 1966.

**NAME 6404: Risk Analysis of Maritime Transport**

3.00 Credit, 3 hrs./wk.
Course Content:

Introduction to the risk concept and other key concepts. Description of the risk picture based on accident statistics, accident theories, accident investigation and analysis. Common methods for risk analysis. Methods for calculating risk for maritime accidents. Human reliability: error mechanisms, influencing factors and modelling approaches. Risk objectives, data and risk acceptance criteria. Risk control measures and options, including cost-benefit analysis.

Reference Book:

- Hazard analysis techniques for system safety by C.A. Ericson, and John Wiley & Sons, 2015.
- Human safety and risk management by A.I. Glendon, S. Clarke, and E. McKenna, CRC Press, 2016.

**NAME 6405: Artificial Intelligence for Marine Engineering**

3.00 Credit, 3 hrs./wk.
Course Content:

Introduction to variant of machine learning methods and application for ship autonomy, potential use of machine learning methods for solving specific problems on autonomous ships, path planning, auto-docking and motion prediction, case studies for each of introduced machine learning methods. Dijkstra method. A* method for path planning for close-range maneuvering. Neural network architecture for ship motion prediction, and force allocation to thrusters. Deep learning method for maritime application.

Reference Book:

- Understanding machine learning: From theory to algorithms by S. Shalev-Shwartz, and S. Ben-David, Cambridge University Press, 2014.
- Machine learning for absolute beginners: a plain English introduction by O. Theobald, Scatterplot Press, 2017.
- Artificial intelligence: a modern approach by S. Russell, and P. Norvig, Pearson, 2020.

**NAME 6406: Advanced Maritime Economics**

3.00 Credit, 3 hrs./wk.
Course Content:

Sea transport and the global economy. The organization of the shipping market. Shipping cycles and forecasting. The shipping market model. Key influences on supply and demand. The demand for sea transport. The supply of sea transport. The freight rate mechanism. The freight market, the freight derivatives market, the sale and purchase market, the newbuilding market, the demolition (recycling) market. Economics of dry bulk shipping, tanker shipping, liner shipping. Maritime finance and risk management. Outsourcing and ship management. Quality shipping. Green shipping. Inter-modular transport system.

Reference Book:

- Maritime Economics by Martin Stopford, Published by Routledge, 2008.
- Shipping and Logistics Management by Yuen Ha (Venus) Lun, Kee Hung Lai, Tai Chiu Edwin Cheng, Springer, London, 2010.

**NAME 6407: Buoy Engineering**

3.00 Credit, 3 hrs./wk.
Course Content:

Statics of mooring lines. Dynamics of mooring lines. Classes and description of oceanographic buoy systems: moored systems, free drifting systems. Buoy system design: system design logic, classes of buoys, external forces to consider in buoy design, materials and fabrication, practical design considerations, metallic and non-metallic mooring lines, chain-connecting hardware-ancillary equipment, anchors. Environmental problems and corrective measures. Deployment and retrieval techniques.

Reference Book:

- Buoy Engineering by Henri O. Berteaux, Publisher: Umi Research Press, 1976.

- Design of a mobile coastal communications buoy by Meghan Hendry-Brogan, Thesis, Department of Ocean Engineering, MIT, 2004.

**NAME 6505: Marine Renewable Energy**

3.00 Credit, 3 hrs./wk.
Course Content:

Renewable ocean energy. Wave energy conversion, storage, and performance. Marine current conversion: tidal resource, tidal devices, and practical resource. Tidal phasing. Ocean thermal energy conversion (OTEC) systems: applicability, thermodynamics, design challenges. Wave energy converters, floating devices, oscillating water column, optimal hydrodynamic performance, current, tidal and offshore wind power. Offshore wind energy: turbine types, fundamentals of operation, airfoils and blades, device and farm-scale flow phenomena. Floating wind foundations, installation and maintenance, logistics and decommissioning, environmental impact. Electrical systems for renewable energy. Renewable energy integration to grid.

Reference Book:

- Fundamentals of Ocean Renewable Energy by Simon Neill, and M Reza Hashemi, Academic Press, 2018.
- Marine Renewable Energy Handbook by Bernard Multon, Wiley-ISTE, 2013.

**NAME 6508: Measurement and Data Analysis**

3.00 Credit, 3 hrs./wk.
Course Content:

Types of measurements and instrumentation in ocean exploration and oceanography, Sensors, and Sampling. Measurements as a function of time and space: A/D converters, Dynamic range, Sampling and Aliasing, Averaging, Time series. Stochastic Processes: Expected values, Probability Density Functions, Stationary and Ergodic Processes, Standard Deviation, Confidence Intervals and Sample Size, Central Limit Theorem. Correlation functions: Auto Correlation, Cross Correlation, Noise Reduction. Spectrum Analysis. Fast Fourier Transforms and Fourier Transforms, Correlation and Spectra, Wavenumber Spectra. Inverse Problems: Concept of Inverse Problems, Linear

Problems, Least Squares Estimates, Fitting Curves and Surfaces, Underdetermined Problems.

Reference Book:

- Random Data Analysis and Measurement Procedures by Bendat, and Piersol, Wiley, 2011.
- Geophysical Data Analysis by Menke, Academic Press, 2012.

**NAME 6601: Mechanics of Water Waves**

3.00 Credit, 3 hrs./wk.
Course Content:

Review of Hydrodynamics: Hydrostatics, Equation of Continuity, Rotational and Irrotational Flows, The Dynamical Equations of Motion, Viscous Flows. Surface Waves: Small Amplitude Wave Theory, Finite Amplitude Waves, Waves creation by winds. Fixed Structure in Waves: Hydrostatic pressure beneath a surface waves, Waves at a vertical Flat Barrier, Consequences of Viscosity, Wave induced forces on a pile, Wave induced vibrations of fixed structures, Wave making drag, Flooding structures in waves, Coupled Heaving and Pitching, Moored and Towed bodies.

Reference Book:

- Ocean Wave Mechanics: Applications in Marine Structures by Dr. V. Sundar, John Wiley & Sons Ltd, 2016.
- Water Wave Mechanics for Engineers and Scientists by Robert G. Dean & Robert A. Dalrymple, 1st edition, 1984.

**NAME 6604: Hydrodynamic Loading of Floating Bodies**

3.00 Credit, 3 hrs./wk.
Course Content:

Overview of fluid mechanics, Linear wave theory, Morrison equation and diffraction theory, Numerical solution of Green function and fluid forces on floating bodies, Governing equation of second order wave drift forces, Wind and current forces and their effects on floating bodies, Response of floating bodies to regular and irregular waves.

Reference Book:

- Sea Loads on Ships and Offshore Structures by O. M. Faltinsen, Cambridge University Press, 1st Edition, 1990.
- Offshore Hydromechanics by J.M.J. Journée and W.W. Massie, Delft University of Technology, 1st Edition, 2001.