Session No. 1478

Development of an Ocean Engineering Course As a Technical Elective for Mechanical Engineers

Eugene E. Niemi, Jr.
Professor
University of Massachusetts Lowell
Lowell, MA 01854

Abstract

This paper outlines the development of a course in Ocean Engineering to be used as a technical elective for mechanical engineering students. With some modifications, the course is also being offered as a technology elective for graduate students in a marine science program. The paper covers the following sequence of events: a sabbatical leave by the course instructor to develop improved capability in this area, textbook selection, course syllabus, and first year experiences teaching the course. A small wave tank was designed and built by some students in conjunction with the first offering of the course, and this is now being used for demonstrations in future offerings of the course.

Introduction

Several years ago, the University of Massachusetts developed a new program called the Intercampus Graduate School of Marine Sciences and Technology (IGSMST), or simply "IGS." This program is a joint program offered through four of the campuses of the UMASS system (Amherst, Boston, Dartmouth, and Lowell). It is a graduate program designed to provide graduates with skills in the marine science area for industry, the government, and academia. The program is described in detail in Ref. 1.

Various departments on each campus are contributing to this program in different ways: some with existing courses and research experience, and others by creating new courses for the program. The Mechanical Engineering Department on the Lowell campus had some research and practical experience in the field of Ocean Engineering and related fields, and had offered a course many years ago called "Mechanical Engineering Problems in Oceanography." A forty foot long wave tank had been used for studying oil spills on water, but long since dismantled, and the department had participated in human-powered submarine projects in previous years (see Ref. 2). A number of graduates from the program had gone on to work in such organizations as the Portsmouth Naval Shipyard, Electric Boat, and the Office of Naval Research. In order to formalize this past experience for the new IGS program, and also to provide increased course opportunities for students in Mechanical Engineering, it was decided to create a new technical elective in Ocean Engineering, to be offered at both the undergraduate and graduate levels. The sequence of events was to include a sabbatical leave for the author to develop additional background in this field, followed by creation and offering of the courses. The sequence used could be used by any college or university to develop a new course in a different area.

Sabbatical Leave

The author of this paper was granted a sabbatical leave during the Spring 2002 semester to take courses related to Ocean Engineering at Florida Atlantic University (FAU). FAU has a strong Ocean Engineering program, and was one of the first schools in the country to develop such a program.

Three courses were studied: a junior level course titled "Oceanography," a senior level course titled "Fluid Mechanics II," and a graduate course titled "Coastal Structures." The Oceanography course was a general summary of physical, chemical, and biological oceanography for Ocean Engineering students. The Fluid Mechanics II course included material on calculation of resistance and performance of ships, as well as marine propeller selection. The Coastal Structures course was a detailed course in wave mechanics, as well as calculation of forces on coastal and offshore structures. Contacts were also made with faculty doing research in this area, attendance at seminars, and field trips and laboratory experiences. Highlights of the program included wave tank demonstrations, flow around model ship hulls, and a field trip aboard the 65 ft MS Stephen to measure ocean properties such as turbidity, salinity, and temperature variation with depth.

Following the sabbatical leave, one summer and a following semester were available for preparing the new courses, and two of the new courses were offered for the first time one year later at the University of Massachusetts Lowell during the Spring 2003 semester.

Course Development

Possible textbooks were evaluated in conjunction with the material learned, and it was decided to use a text by Randall[3] as the primary text, in conjunction with extensive handout material from the Coastal Engineering Manual[4] to fill in where Randall did not go into sufficient detail. The first year, it was decided to offer the course as a technical elective only to the Mechanical Engineering students, to give some time to working the "bugs" out of the course before offering it more broadly through the IGS program. The course was offered as a "dual-numbered" course, on both the undergraduate and graduate levels, all students taking the same course material and tests, but with the graduate students doing two additional projects. Catalog descriptions for these two courses are given below. A syllabus for each of the courses is given in Appendix A.

22.486 Ocean Engineering
Summary of the ocean environment. Fluid mechanics of ocean waves. Modeling and scaling laws for ships, and river and estuary flows. Hydrodynamics of offshore and coastal structures. Floating and submerged body hydrodynamics. Marine propulsion. Introduction to various underwater systems. Prereq: Fluid mechanics.

22.588 Ocean Engineering
Summary of the ocean environment. Fluid mechanics of ocean waves. Computer project in ocean wave interference. Modeling and scaling laws for ships, and river and estuary flows. Hydrodynamics of offshore and coastal structures. Floating and submerged body hydrodynamics. Marine propulsion. Introduction to various underwater systems. Independent research project. Prereq: Permission of instructor.

Examination of these course descriptions shows that the graduate students do an additional computer problem in ocean wave interference, and also do an independent research project in some aspect of Ocean Engineering, which they then present to the entire class. This differentiation between the undergraduate and graduate course is suitable for a first year graduate course. The first year's enrollment was nine undergraduate students and four graduate students.

Wave Tank Development

During the first year offering of the course, but as a separate project, three students elected to design and build a wave tank that could be used for demonstrations and experiments in conjunction with the course. Two of these students were from the Ocean Engineering course. These students built the wave tank for their senior year Capstone Project. The tank was nine feet long, capable of producing waves of various periods and wavelengths, and came out very well, a professionally done project. This wave tank is being used in subsequent offerings of the course.

Course Development for IGS Students

For IGS students, and in the second year offering of the course, the original Ocean Engineering course has been modified into a course called "Ocean Engineering for Marine Scientists." This course is being offered as a "Technology Elective" in two of the option areas that graduate students can take in Marine Sciences: the Marine and Atmospheric System Modeling and Analysis option, or the Marine Observation Technologies option. It is assumed that Marine Science students have a thorough background in oceanography (they take three required core courses in oceanography), but a weaker background in fluid mechanics. For this reason, much of the introductory material in oceanography is omitted, but is replaced by a general review of the basic equations of fluid mechanics. Also, less time is spent on the derivation of the wave equations, rather students are simply taught how to *use* the wave equations. There is also less emphasis on ship calculations and more emphasis on ocean buoys and measurement systems. A catalog description is given below, and a syllabus for the course as offered to marine scientists is presented in Appendix B.

22.584 Ocean Engineering for Marine Scientists

Summary of basic equations of fluid mechanics, continuity, momentum, energy, and Bernoulli. Summary of hydrostatics. Application of equations of fluid mechanics to ocean waves. Hydrodynamics of offshore and coastal structures. Floating and submerged body hydrodynamics. Forces on ocean buoys. Instrumentation systems for ocean research. Independent research project. Prereq: Permission of instructor.

The course "Ocean Engineering for Marine Scientists" is offered by distance learning to the four campuses of the UMASS system participating in the IGS program.

Student and Instructor Impressions

Throughout the first year offering of the course, the students seemed to enjoy the course and the topics presented. The four graduate students were required to give presentations of their independent research projects to the entire class, and most of them went to great effort to give interesting presentations, including two Power Point presentations. The topics presented by the graduate students were offshore oil platforms, materials and corrosion, scaling laws for river and estuary flows, and dive physiology. Students were asked to fill out course evaluation forms and mail them in after the final exam was over. It was the first time the author used this method of course evaluation *after* the final. Unfortunately, only two students returned the survey forms, making the sample too small to be valid. Of the two students returning the evaluations however, both students evaluated the course as a 4.7 out of a possible 5 maximum.

Conclusions

The past two years have seen the development on the UMASS Lowell campus of a total of three courses in Ocean Engineering designed to fill the needs of both mechanical engineers and marine scientists. These courses have built on previous practical and research experience of the department faculty. The courses have been well-received by the students, and the additional training will make our graduates even more marketable in the fields of ocean engineering and marine science.

Bibliography

1. Niemi, E., "An Intercampus Graduate School of Marine Science and Technology," *Proceedings of the 2002 ASEE Annual Conference & Exposition,* Albuquerque, NM, June 2002.
2. Niemi, E. and J.M. Renner, "Development of a Two-Person, Human-Powered Submarine," *Proceedings of the Third International Symposium on Performance Enhancement for Marine Applications,* Newport, RI, May 5-8, 1997.
3. Randall, R.E., *Elements of Ocean Engineering,* SNAME (The Society of Naval Architects and Marine Engineers), Jersey City, NJ, 1997.
4. Anon, *Coastal Engineering Manual,* U.S. Army Corps of Engineers, available on the web.

EUGENE E. NIEMI, JR.
Prof. Niemi received a B.S. in aeronautical engineering from Boston University, an M.S. in mechanical engineering from Worcester Polytechnic Institute, and a Ph.D. from the University of Massachusetts Amherst. His experience includes working at Alden Hydraulic Laboratory, General Electric Steam Turbine Division, and Raytheon Company Missile Systems Division, as well as summers at NASA, Army, and Air Force facilities. He is an avid boater.

Appendix A
22.486/588 Ocean Engineering

Course Syllabus

Text:	Randall, Robert E.., *Elements of Ocean Engineering,* SNAME (The Society of Naval Architects and Marine Engineers), Jersey City, NJ, 1997.
References:	Thurman and Burton, *Introductory Oceanography,* 9th ed., Prentice Hall, 2001. Anon, *Coastal Engineering Manual* (CEM), US Army Corps of Engineers, available on the web. Anon, *Principles of Naval Architecture,* (PNA), SNAME.

Grading:	Two exams (1/3 of course grade each)	2/3 of total grade
	Comprehensive final examination	1/3 of total grade

Topics:

Introduction to the physical characteristics of the ocean. Ocean geography and geology, bathymetry, chemistry, salinity, temperature distribution. Earth's wind patterns, global patterns of ocean circulation and tides. Nomenclature of natural coastal features and man-made coastal structures. Reading: Randall pp. 17-26, 80-89; Reference: Thurman, pp. 146-160, 165-176, 278-305, 312-319. CEM pp. TBA.

Water wave mechanics. Airy's linear wave theory. Celerity (speed) of shallow, transitional, and deep-water waves. Wave group speed. Water particle motion. Equations for wave shape from different wave theories. Pressure distribution under waves. Brief summary of wave refraction, reflection, diffraction, and interference. Reading: Randall pp. 26-40, 90-100. Reference: Thurman pp. 250-269, CEM pp. TBA.

Dimensional analysis and dynamic similarity. Significance of Froude number, Reynolds number, Rossby number, and Weber number. Physical modeling, and criteria for models of rivers, estuaries, submarines, and ships. Towing tanks and water tunnels. Reading: Randall pp. 261-276.

Forces on submerged and floating objects. Buoys and cables, pipelines, sea walls, and pilings, etc. Reading: Randall pp. 58-75, 105-107, 166-177. Reference: CEM pp. TBA.

Forces on ships, submarines, and hydrofoils. Froude's method for calculation of ship resistance. Propulsion, and selection of marine propellers. Reading: Randall pp. 141-165. Reference: PNA pp. TBA

Brief introduction to other ocean engineering topics such as materials and corrosion, acoustics, dive physiology, codes and regulations, etc.

Graduate course: Graduate students taking 22.588 Ocean Engineering must complete all of the undergraduate topics and exams listed above for 22.486 Ocean Engineering. In addition, each graduate student must complete an independent research study on some aspect of ocean engineering at a level beyond that covered in the course, and submit a written summary report as well as give an oral presentation on the topic to the class. Also, graduate students will be given an additional project on calculation of wave interference using computer programs available on-line through the web. For graduate students, the grade distribution listed above will be changed to

Two exams worth 22 ½ % each	45% of total grade
Independent research study	15% of total grade
Computer project on wave interactions	10% of total grade
Comprehensive final examination	30% of total grade

Appendix B

22.584 Ocean Engineering for Marine Scientists
Course Syllabus

Text: Randall, Robert E.., Elements of Ocean Engineering, SNAME (The Society of Naval Architects and Marine Engineers), Jersey City, NJ, 1997.

References: Anon, Coastal Engineering Manual (CEM), US Army Corps of Engineers, available on the web.
Anon, Principles of Naval Architecture, (PNA), SNAME.
Mott, R.L., Applied Fluid Mechanics, Prentice Hall, 5th ed., 2000.
Thurman and Burton, Introductory Oceanography, 9th ed., Prentice Hall, 2001.

Grading:

Two exams worth 22 ½% each	45% of total grade
Computer project on wave interactions	10% of total grade
Independent research project	15% of total grade
Final examination	30% of total grade

Topics:

Summary of the main physical characteristics of the ocean. Ocean geography and geology, bathymetry, chemistry, salinity, temperature distribution. Earth's wind patterns, global patterns of ocean circulation and tides. Nomenclature of natural coastal features and man-made coastal structures. Reading: Randall pp. 17-26, 80-89; Reference: Thurman, pp. 146-160, 165-176, 278-305, 312-319. CEM pp. TBA.

Summary of basic equations of fluid mechanics: continuity equation, momentum equation, energy equation, and Bernoulli equation. Extension of these equations to ocean waves. Reading: Reference: Mott, skim pp. 48-55, 79-87, 115-121, 145-151, 158-163, 191-197, 221-229.

Water wave mechanics. Airy's linear wave theory. Celerity (speed) of shallow, transitional, and deep-water waves. Wave group speed. Water particle motion. Equations for wave shape from different wave theories. Pressure distribution under waves. Brief summary of wave refraction, reflection, diffraction, and interference. Computer project (using online programs) dealing with calculation of wave interference. Reading: Randall pp. 26-40, 90-100. Reference: Thurman pp. 250-269, CEM pp. TBA.

Dimensional analysis and dynamic similarity. Significance of Froude number, Reynolds number, Rossby number, and Weber number. Physical modeling, and criteria for models of rivers, estuaries, submarines, and ships. Towing tanks and water tunnels. Reading: Randall pp. 261-276.

Forces on submerged and floating objects. Buoys and cables, pipelines, sea walls, and pilings, etc. Reading: Randall pp. 58-75, 105-107, 166-177. Reference: CEM pp. TBA.

Instrumentation systems for ocean research. Temperature, pressure, salinity, and wind and current measurement. Use of buoys with instrumentation. Reading: Randall pp. TBA.

Brief introduction to other ocean engineering topics such as materials and corrosion, acoustics, dive physiology, codes and regulations, etc. Independent research study on some aspect of ocean engineering at a level beyond that covered in the course, including written summary report and oral presentation on the topic to the class. Reading: Randall pp. TBA.