Module Handbook Ocean Energy Lisbon

Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Summer Term 2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -
Module reference number/Title: **pre331 - Ocean Energy Resources**	
Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (Master) *This module should be taken in* 2nd semester	*Type of program:* - Lectures, Tutorial, Self-study *Language:* English *Attainable credit points:* 6,00 CP *Workload:* 168 hours *Required attendance:* 50 hours
Person responsible for the programme: Prof. Luis Gato	*Person responsible for this module:* Prof. António Sarmento
Alternative person(s) responsible for this module: Prof. Luis Gato	*Examiner(s):* Prof. António Sarmento
Objective of the module / skills: At the completion of this module, the student will: - have an understanding of the physical mechanisms in the ocean which are on the basis of the generation of surface waves, tides and currents, and their effects, as well as the biological processes that may affect or be affected by ocean energy devices. - be familiar with the statistic description of waves and currents - be able to use the statistical information in order to make evaluation of the energy resource - be able to use GIS for site selection characterization.	
Content of the module: - Introduction to the ocean environment: ocean water and geology; ocean circulation and stratification; ocean habitat; ocean economy. - Ocean surface waves: linear wave theory (regular and random waves); wave spectrum; wave energy resource: parametrical characterisation of ocean waves, nearshore wave transformation, wave measurement and modelling. - Other sources of ocean energy: ocean tidal currents (current measurement; current turbulence; current energy resource); ocean thermal energy conversion; ocean salinity gradient energy	

resource.
- Site selection and characterization for ocean energy systems: criteria on energy resource, expected cost levels, water depth, seabed geology and ecology, distance to shore, ports, O&M bases and electrical grid, marine environmental issues.

Suggested reading:

Apel, J.R.: Principles of Ocean Physics. Academic Press, 1987, 631 pp.

Bakus, G.: Quantitative analysis of marine biological communities. Wiley, 2007.

Boon, J.: Secrets of the tide: Tide and tidal current analysis and predictions, strom surges and sea level trends. West Sussex, UK: Horwood Publishing, Ltd, 2004. 300 pp.

Cartwright, D. E.: Oceanic tides. Rep. Prog. Phys., 1977, 40(6), 665–708.

Goda, Y.: Random Seas and Design of Marine Structures. University of Tokyo Press, Japan, 1985. 323 pp.

Sarpkaya, T. and M. Isaacson: Mechanics of Wave Forces on Offshore Structures. Van Nostrand Reinhold Company, New York, U.S.A., 1981. 651 pp.

Young, I.R.: Wind Generated Ocean Waves. Elsevier Science Ltd, Oxford, UK, 1999. 288 pp.

Roberts, J.: Marine Environment protection and biodiversity conservation. Springer-Verlag Berlin Heidelberg, 2007. 264 pp.

Lerman, M.: Marine Biology: environment, diversity and ecology. Addison-Wesley 1999.

Comments:

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Weblink:

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Prerequisites for admission:

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Helpful previous knowledge:

See general prerequisites

Associated with the module(s):

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Maximum number of students / selection criteria:

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Types of examinations:

Written exam (60%): 2.5 hours

Written report (40%): essay on a chosen topic, 10-20 pages

Examination periods:

Exam: end of lecture period (early June)

Report: deadline end of May

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Summer Term 2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre332 - Modelling and Control of Ocean Energy Systems

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (Master) *This module should be taken in* 2nd semester	*Type of program:* - Lectures, Tutorial, Laboratory, Self-study *Language:* English *Attainable credit points:* 6,00 CP *Workload:* 168 hours *Required attendance:* 56 hours
Person responsible for the programme: Prof. Luís Gato	*Person responsible for this module:* Prof. Falcão de Campos
Alternative person(s) responsible for this module: Prof. António Falcão	*Examiner(s):* Prof. Falcão de Campos, Prof. António Falcão

Objective of the module / skills:

At the completion of this module, the student will:
- be familiar with the linear hydrodynamic theory of wave energy systems
- be familiar with the hydrodynamic theory of marine current turbines (BEM)
- be introduced to advanced numerical hydrodynamic modelling of wave and current systems and control simulation
- be familiar with experimental testing and monitoring of OE systems
- acquire basic knowledge of other forms of ocean energy and their systems as OTEC and salinity gradients.

Content of the module:
- Wave energy systems: Types of wave energy converters. Linear wave structure interactions. Frequency domain analysis. Hydrodynamic coefficients and their computation. Time domain analysis. Phase control. Arrays. Model testing techniques. Marine current turbines. Types of marine current turbines.
- Hydrodynamic models: Blade Element Momentum (BEM), Lifting line (LL), Integral Boundary Element Method (IBEM). Hydrofoil data and analysis. Cavitation and strength. Design criteria. Multiple turbine interaction.
- Other types of energy systems: Ocean Thermal Energy Conversion (OTEC). Energy from salinity gradients.

Laboratory
- Wave Flume of the Civil Engineering Department of IST: Characterization of systems of regular and

irregular 2D waves. Energy spectra. (Duration 3 h).
- Wave Flume of the Civil Engineering Department of IST: Characterization of a floating body response RAO in a system of regular 2D waves. (Duration 3 h).

Suggested reading:

J. Falnes: Ocean Waves and Oscillating Systems. Cambridge: Cambridge University Press, 2002.

G. Thomas: The theory behind the conversion of ocean wave energy: a review. In: (J. Cruz, editor) Ocean Wave Energy. Berlin: Springer, 2008, p. 41-91.

Numerical and experimental modelling of WECs. In: (J. Cruz, editor) Ocean Wave Energy. Berlin: Springer, 2008, p. 133-188.

A. A. Sayigh (Editor): Comprehensive Renewable Energy, vol. 8, Ocean Energy, Elsevier, in press, 2012.

A. F. O. Falcão: Wave energy utilization: a review of the technologies. Renewable and Sustainable Energy Reviews, vol. 14, p. 899-918, 2010.

Lecture Notes. To be produced.

Jack Hardisty: The Analysis of Tidal Stream Power, John Wiley & Sons, 2009, ISBN 9780470724514.

Roger H. Charlier, Charles W. Finkl: Ocean Energy: Tide and Tidal Power, Springer, 2009, ISBN: 3540779310

Comments:

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Weblink:

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Prerequisites for admission:

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Helpful previous knowledge:

Basic courses on:
- Fluid Mechanics
- Thermodynamics
- Applied Mathematical Analysis

Associated with the module(s):

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Maximum number of students / selection criteria:

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Types of examinations:

Written exam (40%): Wave Energy, 2.5 hours

Written exam (50%: Marine Current Turbines, 2.5 hours

Written report (10%): Lab report, 10 - 20 pages

Examination periods:

Written exam (Wave Energy): early April

Written exam (Marine Current Turbines): early June

Written report (Lab): mid-May

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Summer Term 2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre333 - Ocean Energy Systems Technologies

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (Master) *This module should be taken in* 2nd semester	*Type of program:* - Lectures, Tutorial, Laboratory, Self-study *Language:* English *Attainable credit points:* 7,50 CP *Workload:* 210 hours *Required attendance:* 68,5 hours
Person responsible for the programme: Prof. Luís Gato	*Person responsible for this module:* Prof. Luís Gato
Alternative person(s) responsible for this module:	*Examiner(s):* Prof. Luís Gato

Objective of the module / skills:

At the completion of this module, the student will:

- be familiar with the state of the art of electro-mechanical power take-off equipment used in wave energy converters and marine current turbines;
- be familiar with mooring and anchoring systems;
- be familiar with the design and configuration of farms;
- be capable to distinguish the different components and designs of offshore electrical grids;
- acquire basic knowledge on the requirements to deploy, operate and maintain the wave and current energy system;
- be aware of maritime safety issues.

Content of the module:

- Principle of operation and components of air turbines, water turbines, high-pressure hydraulic systems, linear and rotating electrical generators, and energy storage in ocean energy.
- Classification of offshore structures; loads, cost and materials of mooring and anchoring systems; description of anchoring and foundations systems; taut and slack-mooring systems; and mooring configurations in arrays.
- Principles of interference of WEC arrays and layout optimization methods.
- Analysis of tidal turbines arrays.
- Offshore electrical grid structure and components, cable technologies, electrical designs (HVDC vs AC), interaction with the local electricity network, integration into the National grid, examples/case

studies.
- Routine and non-routine offshore operations; management systems; maintenance procedures, risk assessment and inspection plans; and case studies.
- Introduction to offshore operations; vessels, equipment and personnel; method planning and permitting; principles, legislation and standards of safety management.

Laboratory:
- Fluid Mechanics Laboratory of the Mechanical Engineering Department of IST: Testing of an air turbine for use in OWC systems. (Duration 3 h).
- Electrical Machinery Laboratory of the Electrical and Computer Engineering Department of IST: laboratory practice on electrical generators. (Duration 3 h).

Suggested reading:

A. Sayigh: Comprehensive Renewable Energy: Ocean Energy. Elsevier, 2012.

J. Cruz: Ocean Wave Energy: Current Status and Future Perspectives, 2008.

S. Chakrabarti: Handbook of offshore engineering. Elsevier, Vol. 2, 2005.

Carbon Trust: Guidelines on design and operation of wave energy converters, 2005.

EMEC: Guidelines for Health and Safety in the Marine Energy Industry, 2008.

R. E. Harris et al: Mooring systems for wave energy converters: A review of design issues and choices.

B. Child: On the configuration of arrays of floating wave energy converters. PhD thesis, University of Edinburgh, 2011.

I. Alegría et al: Transmission alternatives for offshore electrical power. Renewable and Sustainable Energy Reviews 13, 1027–1038, 2009.

K. Thorburn et al: Wave energy transmission system concepts for linear generator arrays. Ocean Engineering 31, 1339–1349, 2004.

Comments:

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Weblink:

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Prerequisites for admission:

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Helpful previous knowledge:

See general prerequisites

Associated with the module(s):

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Maximum number of students / selection criteria:

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Types of examinations:

Written exam (3 hours)

Examination periods:

Exam week (mid-June)

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Summer Term 2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -

Module reference number/Title:

pre334 - Economics, Policy and Environment

Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (Master) *This module should be taken in* 2nd semester	*Type of program:* - Lectures, Tutorial, Self-study *Language:* English *Attainable credit points:* 4,50 CP *Workload:* 126 hours *Required attendance:* 37,5 hours
Person responsible for the programme: Prof. Luis Gato	*Person responsible for this module:* Prof. António Sarmento
Alternative person(s) responsible for this module: Prof. Luis Gato	*Examiner(s):* Prof. António Sarmento

Objective of the module / skills:

At the completion of this module, the student will:

- be familiar with the basic economic analysis of ocean energy systems including the cost, financing and economic evaluation
- acquire basic knowledge on the general policy issues regarding ocean energy systems and more detailed knowledge on the licensing and permitting procedures for installation of OE systems and enabling mechanisms as funding, feed-in tariffs and tax incentives
- be able to perform simple environmental impact studies for OE systems.

Content of the module:

- Marine spatial planning, concession regimes of marine areas; consenting and licensing of marine farms; feed-in tariffs, green certificates, tax incentives and other financial support mechanics.
- Economic analysis of a marine farm: present and future cost of energy (LCOE, externalities) - the role of offshore energy; characterization of offshore renewable costs (CAPEX and OPEX); project financing: principles (equity, debt ratio), parameters (discount rate, return period, NPV, IRR), tools (Retscreen, etc.) and risk assessment.
- Environmental and socio economic impact assessment and monitoring: EIA objectives, process and requirements; public consultation and conflict of uses management; environmental monitoring; life-cycle assessment.

Suggested reading:

Paillard, M., Lacroix, D., Lamblin, V.: Marine Energy Renewables – Prospective Foresight Study for 2030, Éditions Quae, 2009, ISBN 9782759201839.

Mendonça, M.: Feed-In Tariffs – Accelerating the Deployment of Renewable Energy, Earthscan, 2007, ISBN 9781844077885.

Soares, I., Moreira J., Pinho, C. e Couto J.: Análise Financeira de Projectos, Edições Sílabo, 2007, Portugal.

EWEA: Economics of wind Energy, http://www.ewea.org/fileadmin/ewea_documents/documents/00_POLICY_document/Economics_of_Wind_Energy__March_2009_.pdf

IEA: Projected Costs of Generating Electricity. 2010.

Carbon Trust: Accelerating marine energy, 2011.

Ernst & Young and DECC (UK): Cost of and financial support for offshore wind, 2009.

Comments:

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Weblink:

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Prerequisites for admission:

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Helpful previous knowledge:

See general prerequisites

Associated with the module(s):

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Maximum number of students / selection criteria:

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Types of examinations:

Written exam (60%): 2.5 hours

Written report (40%): essay on a chosen topic, 15-20 pages

Examination periods:

Exam: end of lecture period (early June);

Report: deadline end of May

Registration procedure:

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Fakultät 5: Mathematik und Naturwissenschaften Institut für Physik *Subject:* European Master in Renewable Energy Summer Term 2017	*Category:* - Master Module *Degree award:* - Master
Emphases: -	*Sections:* -
Module reference number/Title: **pre335 - Project**	
Duration: 1 semester *Cycle:* once a year *Type of module:* mandatory *Level:* MM (Master) *This module should be taken in* 2nd semester	*Type of program:* - Lectures, Tutorial, Report work *Language:* English *Attainable credit points:* 6,00 CP *Workload:* 168 hours *Required attendance:* 8 hours
Person responsible for the programme: Prof. Luis Gato	*Person responsible for this module:* Prof. José Maria André
Alternative person(s) responsible for this module: Prof. Luis Gato	*Examiner(s):* Prof. José Maria André
Objective of the module / skills: With the completion of this module, the student will bring into practice the knowledge acquired through a case study in the form of a specific small project.	
Content of the module: This course integrates the knowledge previously acquired by the students regarding the resource evaluation, and the conversion processes. At the end of the course each student should deliver an outline project to explore wave energy in a given site and with a given technology.	
Suggested reading: Literature of the other modules	
Comments: - *Weblink:* - *Prerequisites for admission:* -	*Helpful previous knowledge:* The four other modules of the Specialisation Ocean Energy *Associated with the module(s):* -
Maximum number of students / selection criteria: -	

Types of examinations:

Written report & Presentation: 30 pages written report; 20 min presentation plus 40 min discussion

Examination periods:

Deadline: End of June

Registration procedure:

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