

Course guide

250954 - MECFLUID - Advanced Fluid Mechanics

Last modified: 28/03/2024

Unit in charge: Barcelona School of Civil Engineering

Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering.

Degree: MASTER'S DEGREE IN NUMERICAL METHODS IN ENGINEERING (Syllabus 2012). (Compulsory subject).
ERASMUS MUNDUS MASTER'S DEGREE IN COMPUTATIONAL MECHANICS (Syllabus 2013). (Compulsory subject).

Academic year: 2023

ECTS Credits: 5.0

Languages: English

LECTURER

Coordinating lecturer: PABLO SAEZ VIÑAS

Others: MATTEO GIACOMINI, PABLO SAEZ VIÑAS

TEACHING METHODOLOGY

Taught module delivery: ten weeks of teaching, coursework and self-study. Apart from the 4 hours per week in the classroom, self-study must last an average of 8 hours per week minimum.

Although most of the sessions will be given in the language indicated, sessions supported by other occasional guest experts may be held in other languages.

LEARNING OBJECTIVES OF THE SUBJECT

The course provides the elements to understand the basic tools for the analysis and solution of different types of flows, from the ideal to the viscous flow, contrasting the numerical results with the experiments.

* The students will be able to understand and assimilate the foundations of fluid mechanics * The students will develop practical skills to work with tensors, formulate and develop analysis of diverse problems of solids and fluids in engineering.

The course includes six main topics:

- * Basic concepts and reviews: Summary of vectorial analysis: classic theorems: Greens, Gauss, Stokes - derivative Eulerian/Lagrangian and
- * Reynolds transport theorems.
- * Regulatory Equations: Equations of continuity and laws of conservation. Mass, impulse, and conservation of energy. Classification of equations. Boundary Conditions. Examples
- * Ideal fluids: incompressible, potential irrotational flow. Efficiency,
- * Efficiency functions. Examples.
- * Incompressible viscous fluids: Navier-Stokes incompressible equations: Couette's flow, Poiseuille's flow, Fluids in pipes.
- * Characteristics and equations of compressible fluids.
- * Nature of turbulences
- * Comparison of analytical, numerical, and experimental approaches to solve engineering problems

Learning resources:

- o I.G. Currie, Fundamental Mechanics of Fluids, 2nd edition, McGraw Hill International Editions, 1993.
- o B. Le Mehaute, An Introduction to Hydrodynamics and Water Waves, Springer-Verlag, 1976.
- o A.R. Patterson, A First Course in Fluid Dynamics, Cambridge University Press, 1983.
- o A.J.Chorin & J.E. Marsden, A Mathematical Introduction to Fluid Mechanics, Springer-Verlag, 1979.

Learning objectives: to be able to understand

- the fundamentals of theoretical fluid mechanics: fluid's characteristics and equations of motion,
- the simplifications that can be made leading to models such as incompressible flow, inviscid flow, ideal fluid flow, boundary layer flow, irrotational flow, ...
- how classical solution techniques may be used to solve a range of problems involving these simplified flow problems

Measurable outcomes: to be able to

- identify and solve basic fluid static problems
- obtain and solve Bernoulli's equations
- describe and deduce the potential flow equations and solve them for simplified cases
- select the appropriate boundary conditions and formulate the equations of fluid motion for compressible and incompressible Newtonian fluids
- write a problem in dimensionless form and select the appropriate dimensionless numbers

STUDY LOAD

Type	Hours	Percentage
Hours small group	9,8	7.83
Hours large group	25,5	20.38
Self study	80,0	63.95
Hours medium group	9,8	7.83

Total learning time: 125.1 h

CONTENTS

Review of basic concepts

Description:

Review: stress and body forces; Pascal's law; Archimedes' principle.

Applications: hydraulic force transmission; pressure measurement.

Stratified fluids. Pressure on solid surfaces and immersed bodies

Exercises: mathematical notation (tensors, summation conventions); differential operators and properties; integral theorems.

Full-or-part-time: 7h 11m

Practical classes: 2h

Laboratory classes: 1h

Self study : 4h 11m

Fluid properties

Description:

Description of physical and thermodynamic properties of a fluid

Dimensions and units of measurement

Full-or-part-time: 4h 48m

Practical classes: 1h

Laboratory classes: 1h

Self study : 2h 48m

Governing equations

Description:

Lagrangian and Eulerian description of motion. Material and time derivative. Reynolds' theorem.

Deduction of the conservation equations (mass, momentum and energy).

Streamlines, streak lines, particle paths. Vorticity fields

Fluid constitutive equations. Newtonian and non-Newtonian fluids

Full-or-part-time: 16h 48m

Theory classes: 3h

Practical classes: 3h

Laboratory classes: 1h

Self study : 9h 48m

Dimensional analysis

Description:

Dimensional homogeneity. PI-theorem.

Modeling and applications. Drag and lift.

Full-or-part-time: 7h 11m

Laboratory classes: 3h

Self study : 4h 11m

Inviscid flow: Bernoulli's equation

Description:

Deduction of Bernoulli's equation. Hypothesis
Applications: venturimeter, Pitot tube

Full-or-part-time: 7h 11m

Practical classes: 2h

Laboratory classes: 1h

Self study : 4h 11m

Irrotational flow

Description:

Vorticity. Circulation. Kelvin's theorem. Stream function.
Exercises: plane flows and superposition principle
Potential flow. D'Alembert's paradox

Full-or-part-time: 7h 11m

Practical classes: 2h

Laboratory classes: 1h

Self study : 4h 11m

Test

Description:

Final exam

Full-or-part-time: 14h 23m

Laboratory classes: 6h

Self study : 8h 23m

Incompressible flow

Description:

Velocity-pressure formulation of the Navier-Stokes equations
Dimensionless form.
Stokes equations for viscous flows.

Exercises: Couette flow, Poiseuille flow, pipe flow...

Lubrication theory

Boundary layer theory: hypothesis.

Derivation of the boundary-layer equations

Boundary layer on a flat plate. Boundary layer thickness.

Drag coefficient. Separation. Laminar and turbulent wakes.

Full-or-part-time: 21h 36m

Theory classes: 2h

Practical classes: 6h

Laboratory classes: 1h

Self study : 12h 36m



Examples of application in engineering

Description:

Flow in porous media

Full-or-part-time: 21h 36m

Theory classes: 9h

Self study : 12h 36m

GRADING SYSTEM

The assessment of this module will be based upon submitted exercises (HW), a mid-term examination (Ex1) and an end of semester examination (Ex2).

The final mark will be computed as:

$$0.4*HW + 0.3*Ex1 + 0.3*Ex2$$

EXAMINATION RULES.

The exercises (HW) must be submitted on the announced due date. Work submitted late will normally be awarded half marks. Any late submission must be justified and the lecturer must be informed in advance.

Notes, textbooks, solved problems or any other documents are forbidden during tests.

You may discuss the problems with others, but the worked solutions that you submit are expected to be yours alone.

Unfair practice will be severely punished, in accordance with current academic regulations.

Students must ensure that they do not engage in any form of unfair practice, whereby they take action which may result in them obtaining for themselves or others, an unpermitted advantage.

Unfair practice is defined as any act whereby a person may obtain for himself/herself or for another, an unpermitted advantage. This shall apply whether candidates act alone or in conjunction with another/others. An action or actions shall be deemed to fall within this definition whether occurring during, or in relation to, a formal examination, a piece of coursework, or any form of assessment undertaken in pursuit of the module.

Examples of unfair practice in non-examination conditions are as follows:

- * Plagiarism. Plagiarism can be defined as using without acknowledgment another person's work and submitting it for assessment as though it were one's own work, for instance, through copying or unacknowledged paraphrasing;
- * Collusion. Collusion can be defined as involving two or more students working together, without prior authorisation from the academic member of staff concerned (e.g. Programme leader, lecturer etc) to produce the same or similar piece of work and then attempting to present this work entirely as their own. Collusion may also involve one student submitting the work of another with the knowledge of the originator.
- * Commissioning of work produced by another;
- * Falsification of the results of laboratory, field-work or other forms of data collection and analysis.



BIBLIOGRAPHY

Basic:

- Kundu, P.K.; Cohen, I.M.; Dowling, D.W. Fluid mechanics. 6th ed. Waltham, MA: Elsevier Academic Press, 2016. ISBN 9780124059351.
- Currie, I.G. Fundamental mechanics of fluids. 4th ed. Boca Raton: CRC Press, 2013. ISBN 9781439874608.
- Batchelor, G.K. An Introduction to fluid dynamics. Cambridge: Cambridge University Press, 1973. ISBN 0521663962.
- Chorin, J.; Marsden, J.E. A mathematical introduction to fluid mechanics. 3rd ed. New York: Springer-Verlag, 1992. ISBN 0387979182.
- Fay, J.A. Introduction to fluid mechanics. Cambridge ; London: MIT Press, 1994. ISBN 9788120310445.