Course guide
205223 - TCEA - Turbulence in Aerospace Science and Engineering

Last modified: 22/04/2021

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: **Academic year:** 2021 **ECTS Credits:** 3.0
Languages: English

LECTURER

Coordinating lecturer: JUAN PEDRO MELLADO GONZALEZ

Others:

PRIOR SKILLS

Good knowledge of Fluid Mechanics is required, some knowledge of aerodynamics and propulsion is advantageous.

TEACHING METHODOLOGY

Each session consists of a theoretical part and a practical part. In the practical part, a set of small exercises will be solved and discussed in class to fix the main ideas and concepts of the session. The take-home assignments will also be discussed during this practical part, when needed. The course material will be the course notes, slides, audiovisual material, and a small set of turbulence data to illustrate the analysis approaches described in the course.

LEARNING OBJECTIVES OF THE SUBJECT

This course is an introduction to the fundamental concepts of turbulent flows and its importance in aerospace science and engineering. The course will focus on the physical processes involved in turbulence and turbulent mixing in general configurations such as jets, wakes, shear layers and boundary layers in engineering and in the atmosphere.
At the end of the course, the student will have the background necessary to understand and assess turbulence effects in aerodynamics, propulsion and air traffic management. Furthermore, the student will have the background for advanced courses and research in turbulence analysis and turbulence modeling.

STUDY LOAD

Type	Hours	Percentage
Self study	45,0	60.00
Hours large group	30,0	40.00

Total learning time: 75 h

CONTENTS

Module 1: Introduction to turbulent flows

Description:
The need of studying turbulent flows in aerospace science and engineering. Defining properties of turbulent flows. Methods of Analysis. The Richardson energy cascade as an example of phenomenology and conceptual models.
Short review of Navier Stokes equations, vorticity and dimensional analysis as needed for the remaining of the course.

Full-or-part-time: 12h 30m
Theory classes: 5h
Self study : 7h 30m

Module 2: Mean-flow equations

Description:
Statistical description of turbulent flows. Reynolds decomposition and probability density functions. Derivation and discussion of Reynolds equations. The closure problem.

Full-or-part-time: 12h 30m
Theory classes: 7h 30m
Self study : 5h

Module 3: Variances and Covariances

Description:
Derivation and discussion of Reynolds-stress equations. Two-point statistics, correlation and spectra. Scale separation and the Richardson energy cascade. Kolmogorov hypothesis. Consequences and limitations.

Full-or-part-time: 12h 30m
Theory classes: 5h
Self study : 7h 30m

Module 4: Turbulence modeling

Description:
Direct numerical simulation. Large-eddy simulations. Reynolds-averaged Navier-Stokes. Turbulent-viscosity models.

Full-or-part-time: 12h 30m
Theory classes: 5h
Self study : 7h 30m

Module 5: Reference configurations in aerospace science and engineering

Description:
Major aspects of boundary-free shear turbulence (jet flows, shear layers and wakes). Major aspects of wall-bounded flows (channel flow, pipe flows and turbulent boundary layers). Major aspects of buoyancy effects (atmospheric turbulence and the atmospheric boundary layer).

Full-or-part-time: 25h
Theory classes: 10h
Self study : 15h

GRADING SYSTEM

5 take-home assignments (100% of the final grade).

In case of failing, the grade will be based on one additional written in-class exam on the date fixed in the calendar of final exams. The grade obtained in the additional written in-class exam will range between 0 and 10 and will replace that of the course based on the take-home assignments.

BIBLIOGRAPHY

Basic:

- Pope, Stephen B. Turbulent flows. Cambridge: Cambridge University Press, 2000. ISBN 0521598869.

Complementary:

- Davidson, Peter Alan. Turbulence: an introduction for scientists and engineers. Oxford: Oxford University Press, 2004. ISBN 019852949X.
- Tennekes, H., Lumley, J. L. A first course in turbulence. Cambridge: MIT Press, 1972. ISBN 0262200198.
- Wyngaard, J. C. Turbulence in the atmosphere. Cambridge: Cambridge University Press, 2010. ISBN 9780521887694.