220103 - Fluid Mechanics

Coordinating unit: 205 - ESEIAAT - Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 729 - MF - Department of Fluid Mechanics
Academic year: 2019
Degree: BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Teaching unit Compulsory)
ECTS credits: 4,5
Teaching languages: Catalan, Spanish, English

Coordinator: JOSEP M BERGADA I GRAÑÓ

Opening hours
Timetable: The time table to solve students questions will be given the first day of class.

Prior skills

Students need to have a sufficient level of mathematics and physics, integration, derivation and resolution of simple differential equations it is a previous requirement for this subject.

Requirements

Students need to have passed all mathematical and physics subjects which have to be undertaken in previous semesters.

Degree competences to which the subject contributes

Specific:

1. An understanding of the basic principles of fluid mechanics and their application in solving engineering problems. The ability to calculate pipes, channels and fluid systems.

Teaching methodology

Teaching methodology will be based on classes of theory and problems given by the professor, students will have to solve problems in class and they will also need to solve some exercises at home, the exercises shall be done in groups of two or three students.

Learning objectives of the subject

The main objectives of this subject are, to assure the proper understanding of the basic concepts related to any fluid mechanics subject. This means, to understand the fundamental equations in integral and differential form, flux under dominant viscosity, internal flow and compressible flow. These are the four columns of the subject, although there is no need to say that the rest of the subject is important as well.
## Study load

<table>
<thead>
<tr>
<th></th>
<th>Hours large group:</th>
<th>Hours medium group:</th>
<th>Self study:</th>
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<tbody>
<tr>
<td><strong>Total learning time:</strong></td>
<td>112h 30m</td>
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<td>31h</td>
<td>14h</td>
<td>67h 30m</td>
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<td>27.56%</td>
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### Introduction to fluid mechanics / Statics.

**Learning time:** 10h  
Theory classes: 4h  
Practical classes: 2h  
Self study: 4h

**Description:**  
Fluid under microscopic, macroscopic and thermodynamic points of view. Continuum theory, and local thermodynamic equilibrium. Mechanical and thermodynamic properties of fluids, fluid rheological equations. Basic differential equation of fluid statics, differential equation of a fluid under constant acceleration.  
This description can be summarized as:  
1.1 Mechanical and thermodynamic properties of fluids, properties variation with the thermodynamic state of the fluid.  
1.2 Differential equation for fluid statics.  
1.3 Differential equation of a fluid under constant acceleration and for Cartesian and cylindrical coordinates.

**Related activities:**  
ACTIVITY 1  
ACTIVITY 4

**Specific objectives:**  
The students will acquire a global vision of the different rheological equations of conventional and unconventional fluids, as well as fluid properties. Regarding fluid statics, they will be able to solve any kind of problem related.

### Kinematics of fluids.

**Learning time:** 5h 30m  
Theory classes: 2h  
Practical classes: 1h  
Self study: 2h 30m

**Description:**  
The basic concepts to evaluate fluid movement when viscosity is not considered and fluid is being given as a vector field, will be given in this chapter. The full kinematic analysis of a fluid particle will be undertaken in the present chapter.  
This description can be summarized as:  
2.1 Concept of material derivative, convective flow, circulation and curl.  
2.2 Differential equations of the lines which characterize a non viscous fluid in movement and given as a vector field.  
2.3 Gradient of velocity, deformation and vorticity tensors under all coordinate systems.

**Related activities:**  
ACTIVITY 1  
ACTIVITY 4

**Specific objectives:**  
Given a fluid characterized by a vectorial field, students will learn how to calculate streamlines, path lines, and streak lines. concepts like circulation, curl, convective flow, acceleration, linear and angular deformations, will be part of the knowledge students will gather. Velocity gradient, deformation and vorticity tensors for all coordinate systems, will be defined.
Fundamental equations.

Learning time: 30h
- Theory classes: 6h
- Practical classes: 4h
- Self study: 20h

Description:
This is the main chapter of the course, here all main equations of fluid mechanics in integral and differential form will be defined. An extensive explanation of all main equations for inertial and non inertial references will be undertaken.

This description can be summarized as:
3.1 Reynolds transport theorem.
3.2 Continuity equation in integral and differential form and for all coordinate systems.
3.3 Momentum equation in integral and differential form and under all coordinate systems.
3.4 Energy equation in integral and differential form.
3.5 Momentum of momentum equation.
3.6 Momentum and momentum of momentum equations for non inertial coordinate systems.

Related activities:
ACTIVITY 2
ACTIVITY 4

Specific objectives:
Based on Reynolds transport theorem, all basic equations of fluid mechanics in integral form will be deduced, the next step will be to deduce the basic equations in differential form. The basic equations in differential form will be given in all coordinate systems, Cartesian, cylindrical and spherical. Students will work with all these equations and they will be able to apply them in numerous practical cases, they will also learn to use the appropriate equations in inertial and no inertial reference systems.
**Flow with dominant viscosity.**

**Learning time:** 16h
- Theory classes: 4h
- Practical classes: 2h
- Self study: 10h

**Description:**
Under dominant viscosity, it is understood that the movement of the fluid is driven by viscous forces, inertial forces play an irrelevant role. This chapter will focus in the use of continuity and momentum equations in differential form. Their application in flat and cylindrical journal bearings will be clarified.

This description can be summarized as:
- 4.1 Couette and Poiseulle flow in flat plates and ducts.
- 4.2 Poiseulle flow in concentric cylinders.
- 4.3 Flat and cylindrical journal bearings.

**Related activities:**
- ACTIVITY 3
- ACTIVITY 4

**Specific objectives:**
In this chapter the students will learn to apply Navier Stokes equations between two parallel plates, and in Cartesian, cylindrical and spherical coordinates. It will be studied the flow of Couette, Poiseulle, Haguen-Poiseulle and Rayleigh. Reynolds lubrication equations will be studied, the students will learn how to calculate a flat and a cylindrical journal bearings. The application to high speed engines and aeroplane engines is direct.
### Dimensional analysis / Theory of models.

**Learning time:** 6h  
Theory classes: 3h  
Self study: 3h

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| In this chapter, the basis to optimally perform any experimental measurement in fluid mechanics will be given. The key lies in the characterization of a physical phenomena using non dimensional groups. The use of non dimensional groups to extrapolate results between a model and a prototype, will be explained in the second part of the chapter, where it will be seen which problems appear whenever this extrapolation is to be done. This description can be summarized as:  
5.1 Theorem of pi or Buckingham, matrix system and normalization of equations.  
5.2 Non dimensional groups related to fluid mechanics, parameters related.  
5.3 Theory of models, geometric, kinematic and dynamic similarities, associated problems. |  |

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<thead>
<tr>
<th>Related activities:</th>
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<tbody>
<tr>
<td>ACTIVITY 5</td>
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<td>ACTIVITY 8</td>
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<th>Specific objectives:</th>
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<td>Students will learn the different methods to find out the non dimensional groups which characterize a physical phenomenon. The most used in fluid mechanics non dimensional groups and which physical phenomenon is related to each of them will be clarified. Students will learn the similarity laws which need to be fulfilled to extrapolate results between model and prototype, they will also understand which non dimensional groups are connected to each similarity law. The problems associated to the application of similarity laws will be clearly defined.</td>
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Boundary layer / External flow.

Learning time: 7h
Theory classes: 3h
Self study: 4h

Description:
The explanation of why fundamental equations in integral form are not producing good results when applied to external flow, flow around bluff bodies, lies in the understanding of what happens in the fluid regions nearby the body, regions where the boundary layer appears. In the present chapter, equations which define the laminar and turbulent boundary layer will be studied, it will be seen how fluid flowing around bluff bodies is being affected by small perturbations generated on the boundary layer.

This description can be summarized as:
6.1 Differential equation of Prandtl for laminar boundary layer, Blasius solution, integral equation of Von Karman.
6.2 Application of the Von Karman equation in the laminar and turbulent parts of a flat plate boundary layer. The basic equations which characterize the boundary layer parameters under laminar and turbulent conditions will be obtained.
6.3 Non dimensional groups characterizing external flow.
6.4 Concepts of free and forced vortex, Magnus effect.

Related activities:
ACTIVITY 5
ACTIVITY 8

Specific objectives:
Among the objectives of this paper, it is necessary to point out the capacity students will acquire to analyze the different parameters which characterize the boundary layer. The students will understand why understanding what happens inside the boundary layer, it is decisive to foresee how fluid will affect the bluff body under study. The application of the gathered knowledge in external flow and the analysis of the forces fluid generates on bluff bodies, including the Magnus effect, will be considered on the second part of this chapter.
Internal flow.  

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<tr>
<td>Theory classes: 3h</td>
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<td>Practical classes: 2h</td>
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<td>Self study: 8h</td>
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**Description:**
This chapter is a classic in industrial engineering, here the fluid will be treated as incompressible and therefore the equations used will be specially simple. Nevertheless what will be studied here it is highly applicable in practice, then fluid transport in pipes with the help of pumping systems is widely used.

This description can be summarized as:

7.1 The use of the energy equation in pipes, concept of linear and singular losses. Moody diagram.
7.2 Different kind of problems which may appear in the study on incompressible flow in ducts.
7.3 Pipelines in serial and parallel, concept of hydraulic diameter and equivalent length.
7.4 Introduction of hydraulic machinery in pipelines.

**Related activities:**
ACTIVITY 6
ACTIVITY 8

**Specific objectives:**
Students will learn to design pipelines to transport fluids. The existing different calculation cases will be studied. Parameters and equations to be used to define energy losses in pipes will be clarified. Systems in serial and parallel as well as how to implement hydraulic machinery in a pipeline will be perfectly known by all students.
### Compressible flow.

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<th>Learning time: 25h</th>
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<tbody>
<tr>
<td>Theory classes: 6h</td>
</tr>
<tr>
<td>Practical classes: 3h</td>
</tr>
<tr>
<td>Self study : 16h</td>
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**Description:**
When the fluid is a gas and flows inside a pipe, it is very likely that treating this fluid as incompressible will not be sufficient. It will therefore be necessary to study the fluid as compressible. In the present chapter, it will be defined which is the boundary from which fluid shall be considered as compressible. Subsonic and supersonic treatment, including chocked waves and for internal and external flow, will be covered in this chapter.

This description can be summarized as:

- **8.1 Equations for isentropic flow.**
- **8.2 Weak waves, concept of sound speed, Mach number and the Mach cone.**
- **8.3 Isentropic flow in convergent-divergent nozzles. Concept of chocked flow, flat and oblique chocked waves.**
- **8.4 Compressible flow in tubes, Fanno, isothermal and Rayleigh flows.**

**Related activities:**
- ACTIVITY 7
- ACTIVITY 8

**Specific objectives:**
Once defined the limit from which fluid has to be mathematically treated as incompressible, students will work with the existing cases, Fanno, isothermal and Rayleigh. They will understand the equations which characterize each case and the process of calculation required. Flow inside convergent-divergent nozzles and its application to real cases, will be another important part of this chapter. All students will understand when and why chocked waves will appear and they will be able to analyze them mathematically.
### Planning of activities

<table>
<thead>
<tr>
<th>ACTIVITY 1</th>
<th>Hours: 14h</th>
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<tr>
<td>ACTIVITY 2</td>
<td>Hours: 20h</td>
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<tr>
<td>ACTIVITY 3</td>
<td>Hours: 17h</td>
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#### Description:

**ACTIVITY 1**

Students in groups of two or three people, will need to do at home several exercises in order to get a deeper understanding of the theory presented in class. The exercises in this first activity will be related with the first and second chapter of the subject.

**Support materials:**

To do the homework, students shall use all existing information, books, articles, web pages etc.

**Descriptions of the assignments due and their relation to the assessment:**

The work will need to be presented in a given date and before the first examination date. The work will be presented in digital form and using ATENEA.

**Specific objectives:**

The objectives of all exercises the students will do during the course are, to insure a good understanding of the main concepts involved in each chapter, to learn how to search for scientific information and to improve their skills in working with teams.

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**ACTIVITY 2**

Students in small groups will do at home several exercises to improve their understanding of each chapter of the subject.

**Support materials:**

Students are allowed to use all information of any source to perform the work.

**Descriptions of the assignments due and their relation to the assessment:**

The work will need to be given until a fixed date, which will always be before the date of the first exam. Work shall be presented in digital format and using ATENEA.

**Specific objectives:**

The objectives are: to improve the knowledge of a particular chapter, learn how to search for scientific information in order to solve the proposed exercises and learn how to work in teams.

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**ACTIVITY 3**

In small groups, students will have to do several exercises related with chapter four of the subject.

**Support materials:**

They can use anything available.
ACTIVITY 4 - FIRST EXAM

Description:
This is the first partial exam of the subject.

Support materials:
Students shall bring a sheet with mathematical expressions used during this first part of the subject.

Descriptions of the assignments due and their relation to the assessment:
Exercises will be presented before a limit date, which will be before the first exam. The information will be given in digital form and using ATENEA.

Specific objectives:
The objectives are to improve the knowledge of a particular chapter, learn how to search for information and improve the team working skills.

ACTIVITY 5

Description:
Students in small groups will undertake exercises, to improve their knowledge of the subject, to be done at home. This activity is linked with chapters five and six of the subject.

Support materials:
Students are allowed to use all resources they might be having at hand.

Descriptions of the assignments due and their relation to the assessment:
Work will be given until a fixed date, and always before the final exam of the subject. The assignments will be given in digital form and using ATENEA.

Specific objectives:
The objectives are: To improve the knowledge of the subject, search for scientific information and improve the skills to work in a team.

ACTIVITY 6

Description:
In small groups students will do proposed exercises at home, this activity is linked with exercises of chapter 7 of the subject.
Support materials:
Students are allowed to use all kind of resources they might feel they need.

Descriptions of the assignments due and their relation to the assessment:
Work will be presented in digital form and using ATENEA. The assignments will need to be presented before a given date.

Specific objectives:
The objectives of activity 6 are: to allow the students to improve their knowledge of the subject, to direct them into searching scientific information and to improve their skills in working with teams.

ACTIVITY 7

Description:
As in all previous assignments, students in small groups will have to do some exercises at home in order to improve their knowledge of the subject.

Support materials:
Students can use any scientific source to achieve their assignment.

Descriptions of the assignments due and their relation to the assessment:
Work will be presented in digital form and using ATENEA. It will need to be presented before a given date.

Specific objectives:
To improve students' knowledge, search of scientific information and work in teams, are among the objectives of this activity.

ACTIVITY 8 - FINAL EXAM

Description:
This is the second and final exam of the subject.

Support materials:
Just a sheet of paper with all the mathematical expressions used in the subject can be brought.

Descriptions of the assignments due and their relation to the assessment:
In paper form and at the end of the exam.

Specific objectives:
This activity aims to evaluate the students gathered knowledge.
Qualification system

The semester will be divided in two parts, during the first part, students will need to do three exercises at home, and their overall value will be 15% of the subject, at the end of the first part, it will need to be done the first exam which value will be 35% of the subject. On the second part of the semester, again three exercises will be done by the students at home, and at the end of the course the final exam will take place. The value of the second set of exercises and the final exam will be the same as in the first part of the semester. Each exam will consist of three problems.

The subject establishes the following methodology to redirect the unfavorable results. In the second exam, an extra problem having a value of 35% of the total value of the first exam, will be given. The qualification obtained in this extra problem will substitute the smallest of the three qualifications obtained in the first exam, understanding that the original qualification of the first exam cannot be decreased. Regarding the six exercises the students need to do during the semester, the students will have the opportunity of redoing any of them which qualification happens to be equal or smaller than 6.

Regulations for carrying out activities

The six exercises the students will need to do at home, shall be done with the aid of a computer, and will be downloaded via ATENEA. Each group will need to present its work, having 30 minutes to do so. The qualification obtained will depend on the work developed and the presentation of it. During the presentation, the professor shall ask questions regarding the work done.

The two exams each student will need to do, will take 2 hours 30 minutes each, the exam will consist mostly on the resolution of problems, although theoretical questions could also be asked.
Bibliography

Basic:


Complementary:


Others resources:

Information left in ATENEA and information to be found in web pages related to fluid mechanics.

Hyperlink

Informació deixada a ATENEA

Power point notes of the subject and collections of solved problems.

www.efluids.com

Web page related to fluid mechanics.

www.cfd-online.com

Web page with information related with computational fluid mechanics.

www.potto.org

Web page related to fluid mechanics.