Name: Continuum Mechanics: Fluids - 34052

Type: introductory **Semester:** 1st

ECTS: 7.5

Periodicity: annual

Departments involved: Department of Applied Physics (UPC)

Coordinator: Marta Net Marcé

Professors: Albert Falqués Serra, Vicente Iranzo Fernández, Marta Net Marcé

Language: Catalan / Spanish / English

Prerequisite: Vector and tensor calculus. Methods for solving EDO's**.**

Aims:

The purpose of the course is to give a systematic introduction to continuum mechanics. The fundamental laws will be mainly applied to particular fluid problems, such as boundary layer, gravity waves, or thermal convection problems, among others. On the other hand, it tries to give to the student interested in fluid mechanics a wide knowledge of the basic phenomena, and the tools needed to achieve a proper research training in high level courses.

Syllabus:

1. Tensorial Calculus

1.1 Scalars, vectors and tensors. Cartesian tensors. Intrinsic and matrix notation. Product and contraction. Isotropic tensors. Second order tensors. Symmetric and antisymmetric tensors. Eigenvalues and eigenvectors. Alternating tensor.

1.2 Tensorial fields. Gradient, divergence and curl. Gauss and Stokes theorems. Vectorial identities. Diferential operators in curvilinear coordinates.

2. Flow Kinematics

2.1 Eulerian and Lagrangian description. Material derivative

2.2 Streamlines, pathlines and streaklines Material lines, surfaces and volums

2.3 Shearing-rate, rotation-rate and deformation-rate tensor. Rate of change of line, surface and volume elements

2.4 Rate of change of material integrals

2.5 Vorticity and Circulation

3. Conservation laws

3.1 Shear-stress tensor. Normal and shear stresses. Cauchy equation

3.2 Conservation of mass. Continuity equation

3.3 Balance of linear and angular momentum

3.4 Conservation of Energy. Heat conduction, Intern energy, and First law of thermodynamics.

3.5 Second law of thermodynamics: Entropy production

3.6 Constitutive equations. Solids, liquids and gases.

4. Newtonian fluids

4.1 Euler and Navier-Stokes equations. Boundary conditions

4.2 Vorticity dynamics. Vortex lines and vortex tubes

4.3 Kelvin's circulation theorem. Vorticity equation

5. Potential flow

5.1 Potential velocity. Laplace equation. Examples

5.2 Flow past a body. Force and linear momentum. Blasius' integral laws

5.3 Kutta-Zhukhovski lift theorem

5.4 Conformal mapping. Applications

5.5 Three-dimensional potential flows. Axisymmetric flows. Stokes streamfunction. Solution of the potential equation

6. Surface waves

6.1 Linear theory. Phase and group velocities

6.2 Surface and gravity waves. Energy considerations

6.3 Deep and shallow water approximations

6.4 Group velocity and energy flux. Dispersion relation

6.5 Nonlinear waves in non-dispersive media

7. Internal waves

7.1 Equations of motion for a continuously stratified fluid

7.2 Solution of the equations. Dispersion and energy considerations

8. Viscous incompressible flows

8.1 Dynamic similarity. Buckingham's Pi theorem. Physical meaning of common nondimensional parameters

8.2 Exact solutions of the Navier-Stokes equation. Examples

8.3 Diffusion effects. Examples

8.4 Low and high Reynolds number flow. Examples of solutions at low Reynolds number

9. Thermal convection: Effects of the rotation and of the concentration

9.1 Boussinesq approximation. Free and forced convection. Thermal and viscous boundary layers. Examples. The Bénard problem

9.2 Navier-Stokes equations in rotating systems. Centrifugal and Coriolis forces. Taylor-Proudman theorem. Ekman boundary layer

9.3 Double-diffusive convection. Binary mixtures. Soret and Duffour effects

10. Boundary layers. Wakes and jets

10.1 Boundary layer approximation

10.2 Laminar boundary layer. Blasius solution

10.3 Karman momentum integral. Karman-Pohlhausen approximations.

10.4 Effects of the pressure gradient. Separation conditions

10.5 Description of: Flow past a circular cylinder and a sphere

10.6 Two-dimensional jets. Perturbation techniques

10.7 Aerodynamics. Generation of circulation. Lift and drag characteristics of airfoils

11. Compressible non-viscous flows

11.1 Basic equations and boundary conditions

11.2 One-dimensional shock waves

11.3 Mach cone

Method:

The topics will be introduced in lectures interspersed with discussions and examples. However, some contents can be introduced and/or illustrated with movies. In the practical classes every student will expose cyclicly its solution to proposed problems, based on the topics of the lectures.

Evaluation:

The method of evaluation is thought to balance the knowledge acquired, and the skill in dealing with fluid mechanics problems.

The final mark will be obtained 50% from a continual evaluation, and 50% from a final written exam, although the scope and method of evaluation can be adapted each course if needed.

Bibliography:

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