UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

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230467 - MEC - Mechanics

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics
Academic year: 2019
Degree: BACHELOR'S DEGREE IN ENGINEERING PHYSICS (Syllabus 2011). (Teaching unit Compulsory)
ECTS credits: 6 Teaching languages: Catalan

Teaching staff

Coordinator: Marques Truyol, Francisco

Others: Torres Herrera, Ramon
Gil Pons, Pilar

Opening hours

Timetable: Francesc Marqués: wednesday 11-13 or by appointment.

Degree competences to which the subject contributes

Specific:
1. Ability to solve problems in thermodynamics, heat transfer and fluid mechanics, in the fields of physics, aerodynamics, geophysics and engineering.

Generical:
1. ABILITY TO IDENTIFY, FORMULATE, AND SOLVE PHYSICAL ENGINEERING PROBLEMS. Planning and solving physical engineering problems with initiative, making decisions and with creativity. Developing methods of analysis and problem solving in a systematic and creative way.

Transversal:
2. EFFECTIVE USE OF INFORMATI0N RESOURCES - Level 2. Designing and executing a good strategy for advanced searches using specialized information resources, once the various parts of an academic document have been identified and bibliographical references provided. Choosing suitable information based on its relevance and quality.
3. SELF-DIRECTED LEARNING - Level 2: Completing set tasks based on the guidelines set by lecturers. Devoting the time needed to complete each task, including personal contributions and expanding on the recommended information sources.

Teaching methodology

There are two types of lectures: theoretical and practical. The main concepts and the fundamental results along with some examples and practical applications are discussed in the theoretical lectures. The practical lessons are devoted to solving exercises and a more active participation of the students is expected. Additional examples and applications are also discussed in the practical lectures.

Learning objectives of the subject

- Ability to identify the freedom degrees and generalized coordinates of a system of particles and rigid bodies.
- Ability to write de Lagrange and Hamilton equations of motion for any mechanical system.
- Knowledge of the concepts of equilibrium, stability and linearization of the equations of motion.
- Ability to linearize the equations of motion and write the equations for the eigenfrequencies and normal modes.
- Ability to pose dynamical problems for 2D and 3D rigid bodies.
- Knowledge of the concept of fluid and its fundamental properties: pressure, compressibility, viscosity, surface tension.

- Ability to determine the pressure distribution for fluid at rest both in an inertial and non inertial frame.
- Knowledge of the fundamental characteristics of fluid motion: velocity field, streamlines, spatial and material descriptions, local and convective time derivatives, vorticity, steady and unsteady flows, Reynolds number, laminar and turbulent flows, boundary layer.
- Knowledge of the fundamental laws of fluid dynamics: mass, momentum and energy conservation. Ability to set up the balance for a control volum. Knowledge of the local equations: continuity, Navier-Stokes, Euler and Bernouilli.
- Ability to set up the computation of the force of a fluid on a body.
- Learning some practical applications: Lubrication and viscous adherence, swimming, pipe flow, propellors and turbines, drag and lift forces, elementary aspects of ocean waves, cyclonic and anticyclonic motions in a rotating planet.

Study load

Total learning time: 150h	Hours large group:	65h	43.33%
	Self study:	85h	56.67%

Content

1. Lagrangian formulation of Mechanics.	Learning time: 16h Theory classes: 4h Practical classes: 3h Self study : 9h

Description:
1.1. Revisiting the laws of Mechanics: momentum and energy. Examples.
1.2. Holonomic constraints. Virtual work principle.
1.3. Generalized coordinates and equations of motion. Lagrange equations.
1.4. Generalized potentials.
1.5. Examples: central forces and gravitation.
1.6. Variational equations and action principle.

2. Small oscillations.	Learning time: 16h Theory classes: 4h Practical classes: 3h Self study : 9h

Description:
2.1. Linearization at an equilibrium point. Stability.
2.2 Eigenvalue equation. Diagonalization of T and V.
2.3. Normal modes of motion. Examples.
2.4. Forced oscillations and resonance.
2.5. Nonlinear oscillations.

3. Hamilton formulation.	Learning time: 17h Theory classes: 5h Practical classes: 2h Guided activities: 1h Self study : 9h

Description:
4.1. Generalized moments and Hamilton function.
4.2. Poisson brackets.
4.3. Liouville's theorem.
4.4. Conservation laws. Noether's theorem.
4.5 Example: central forces.

4. Introduction to Physics of Fluids. Hydrostatics.	Learning time: 14h Theory classes: 3h Practical classes: 3h Self study : 8h

Description:
5.1. Definition of a fluid and properties.
5.2. Pressure. Stress tensor.
5.3. Hydrostatic equation. Pressure vertical distribution.
5.4. Forces on a submerged body.
5.5. Buoyancy force and stability.

5. Fluid kinematics	Learning time: 9h Theory classes: 2h Practical classes: 2h Self study : 5h

Description:
6.1. Velocity field. Steady flow. Acceleration field. Convective derivative.
6.2. Spatial and material descriptions.
6.3. Path lines, streamlines and stream tubes.
6.4. Material volums and surfaces.

6. Laws of Fluid Dynamics.	Learning time: 17h Theory classes: 4h Practical classes: 3h Guided activities: 1h Self study : 9h

Description:
6.1. Time derivative of integrals on a variable volume.
6.2. Conservation of mass, momentum and energy: global and local form.
6.3. Rate of cahnge in fixed or moving control volumes.
6.4. Aplications.

7. Inviscid flow.	Learning time: 15h Theory classes: 3h Practical classes: 3h Self study : 9h

Description:
7.1. Incompressible inviscid flow: Euler equations.
7.2. bernouilli equation.
7.3. pipe flow. Head loss (with an experiment).
7.4. Pitot tube, Venturi effect, reservoirs.
7.5. Propellor and eolic power.
7.6. Introduction to 2D potential incompressible flow.

8. Viscous flow.	Learning time: 30h Theory classes: 8h Practical classes: 4h Guided activities: 1h Self study : 17h

Description:
8.1. Flow between parallel plates and viscosity.
8.2. Newtonian fluids. Navier-Stokes equations.
8.3. Simple laminar solutions. poiseuille flow and Couette flow.
8.4. Simple examples of nonsteady solutions.
8.5. Reynolds number. Instability and turbulence.

9. Vorticity dynamics and boundary layer.	Learning time: 9h Theory classes: 4h Practical classes: 0h Self study : 5h

Description:
9.1. Vorticity equation and applications.
9.2. Vorticity lines and voticity tubes.
9.3. Inviscid flow and the role of viscosity.
9.4. Boundary layes on a flat plate: Blasius solution.
9.5. General features of boundary layer: wakes, vortices, turbulence.

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10. Drag and lift.	Learning time: 7h Theory classes: 2h Practical classes: 1h Self study : 4h
Description: 10.1. Flow about a body. Drag and lift forces. 10.2. Drag and lift coefficients: empirical values. 10.3. Drag force and circulation. Magnus effect. 10.4. Airplanes flight and sailing boats.	

Qualification system

The grading process consists of a final exam (EF), two partial exams (EP1, EP2) and the participation of the students in the practical lectures (P). The first partial exam will be held at mid semester and both the final exam and the second partial exam will be held the same day at the end of the semester.
The final grade will be: max{EF,0.31*EP1+0.62*EP2+0.07*P}

Bibliography

Basic:

Taylor, J.R. Classical mechanics. Sausalito, California: University Science Books, 2005. ISBN 189138922X.

Spurk, J.H.; Aksel, N. Fluid mechanics. Berlin: Springer, 2008. ISBN 9783540735366.

Fox, R.W.; McDonald, A.T.; Pritchard, P.J. Introduction to fluid mechanics. 7th ed. USA: John Wiley & Sons, 2008. ISBN 9780471742999.

Complementary:

Symon, K.R. Mechanics. 3rd ed. Reading, Massachusets: Addison Wesley, 1971. ISBN 0201073927.

White, F.M. Mecánica de fluidos. 6a ed. Madrid: McGraw-Hill, 2008. ISBN 9788448166038.

Spurk, J.H. Fluid Mechanics: problems and solutions. Berlín: Springer, 1997. ISBN 3540616527.

Hand, L.N.; Finch, J.D. Analytical mechanics. Cambridge: Cambridge University Press, 1998. ISBN 052157572.

Acheson, D.J. Elementary fluid dynamics. Oxford: Clarendon Press, 1990. ISBN 0198596790.

Kundu,P.K.; Cohen, I.M. Fluid mechanics. 5th ed. San Diego ; London: Academic Press, 2011. ISBN 9780123821003.

Goldstein, H.; Poole, C.; Safko, J. Classical mechanics. International ed. Pearson, 2014. ISBN 9781292026558.

Cushman-Roisin, B. Introduction to geophysical fluid dynamics [on line]. 2nd ed. Academic Press, 2011 [Consultation: 04/07/2012]. Available on: <http://site.ebrary.com/lib/upcatalunya/docDetail.action?docID=10501108>. ISBN 9780080916781.

Çengel, Y.A.; Cimbala, J.M. Mecánica de fluidos : fundamentos y aplicaciones [on line]. 2a ed. México: Mc Graw-Hill, 2012 [Consultation: 08/11/2018]. Available on: <http://www.ingebook.com/ib/NPcd/IB_BooksVis?cod_primaria=1000187&codigo_libro=5644>. ISBN 9786071507792.

Others resources:

List of exercises to solve