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.

General:
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 INFORMATION 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.
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- 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 volume. Knowledge of the local equations: continuity, Navier-Stokes, Euler and Bernoulli.
- 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.

<table>
<thead>
<tr>
<th>Study load</th>
<th>Hours large group: 65h</th>
<th>43.33%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total learning time: 150h</td>
<td>Self study: 85h</td>
<td>56.67%</td>
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</table>
## Content

<table>
<thead>
<tr>
<th>1. Lagrangian formulation of Mechanics.</th>
<th>Learning time: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
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<tr>
<td></td>
<td>Practical classes: 3h</td>
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<tr>
<td></td>
<td>Self study : 9h</td>
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</tbody>
</table>

### Description:
5. Examples: central forces and gravitation.

<table>
<thead>
<tr>
<th>2. Small oscillations.</th>
<th>Learning time: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 3h</td>
</tr>
<tr>
<td></td>
<td>Self study : 9h</td>
</tr>
</tbody>
</table>

### Description:
1. Linearization at an equilibrium point. Stability.
2. Eigenvalue equation. Diagonalization of T and V.
4. Forced oscillations and resonance.
5. Nonlinear oscillations.

<table>
<thead>
<tr>
<th>3. Hamilton formulation.</th>
<th>Learning time: 17h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 5h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 2h</td>
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<tr>
<td></td>
<td>Guided activities: 1h</td>
</tr>
<tr>
<td></td>
<td>Self study : 9h</td>
</tr>
</tbody>
</table>

### Description:
2. Poisson brackets.
3. Liouville’s theorem.
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:**
- 6.2. Spatial and material descriptions.
- 6.3. Path lines, streamlines and stream tubes.
- 6.4. Material volumes and surfaces.


**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 change in fixed or moving control volumes.
- 6.4. Applications.
### 7. Inviscid flow.

**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.

**Learning time:** 15h
- Theory classes: 3h
- Practical classes: 3h
- Self study: 9h

### 8. Viscous flow.

**Description:**
- 8.1. Flow between parallel plates and viscosity.
- 8.4. Simple examples of nonsteady solutions.
- 8.5. Reynolds number. Instability and turbulence.

**Learning time:** 30h
- Theory classes: 8h
- Practical classes: 4h
- Guided activities: 1h
- Self study: 17h

### 9. Vorticity dynamics and boundary layer.

**Description:**
- 9.1. Vorticity equation and applications.
- 9.2. Vorticity lines and vorticity tubes.
- 9.3. Inviscid flow and the role of viscosity.
- 9.5. General features of boundary layer: wakes, vortices, turbulence.

**Learning time:** 9h
- Theory classes: 4h
- Practical classes: 0h
- Self study: 5h
10. Drag and lift.

**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.

**Learning time:** 7h
- Theory classes: 2h
- Practical classes: 1h
- Self study: 4h

**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: \( \text{max}\{EF,0.31\times EP1+0.62\times EP2+0.07\times P\} \)

**Bibliography**

**Basic:**

**Complementary:**

**Others resources:**
- List of exercises to solve