### Degree competences to which the subject contributes

#### Specific:
1. **CG04** - Ability to research, design, develop and implement simulation methods for the control of electronic systems, automatic and robotic.
2. **CB9** - Students can communicate their conclusions, knowledge and rationale underpinning these, to skilled and unskilled public in a clear and unambiguous way.
3. **CB7** - Students can apply their knowledge and their ability to solve problems in new or unfamiliar contexts within broader (or multidisciplinary) contexts related to their field of study.

#### Teaching methodology

In the lectures, the instructor presents some motivating ideas, the fundamental concepts, and some relevant developments, intermingled with key examples and the resolution of representative problems.

In laboratory classes, the students learn to use MATLAB to solve different kinds of problems that will be assigned in each session. Every week, the second session will be assessed.

#### Learning objectives of the subject

1. Calculate the curve (function) that maximizes or minimizes an integral (functional).
2. Know if a system described by ODE (state space) can be controlled by an external input (control function).
3. Compute the optimal control for systems controllable.
4. Know and use MATLAB and SIMULINK to solve ODE numerically.
5. Use MATLAB and SIMULINK to solve different kinds of exercises.
## Study load

<table>
<thead>
<tr>
<th>Total learning time: 125h</th>
<th>Hours large group: 22h 30m 18.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours medium group: 0h 0.00%</td>
</tr>
<tr>
<td></td>
<td>Hours small group: 22h 30m 18.00%</td>
</tr>
<tr>
<td></td>
<td>Guided activities: 0h 0.00%</td>
</tr>
<tr>
<td></td>
<td>Self study: 80h 64.00%</td>
</tr>
</tbody>
</table>
## Content

### 1. Introduction

**Description:**

We introduce with historic examples the several problems that we explain in this subject: optimal function, calculus of variations and optimal control problems.  

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

### 2. Calculus of variations

**Description:**

2.1 Problem Statement.  
2.2 Basic theory: necessary condition, Euler-Lagrange equation.  
2.3 Particular cases.  
2.4 Generalizations of the Euler-Lagrange equation.  
2.5 Variable endpoints.  

**Learning time:** 16h  
- Theory classes: 5h  
- Self study: 11h

### 3. Lagrange Multipliers

**Description:**

3.1 Constrained maximization or minimization of a function: Lagrange multipliers theory.  
3.2 Constrained calculus of variations.  

**Learning time:** 6h  
- Theory classes: 2h  
- Self study: 4h

### 4. Controllability

**Description:**

4.1 Controllability of control linear systems.  
4.2 Examples.  

**Learning time:** 6h  
- Theory classes: 2h  
- Self study: 4h
### 5. Optimal Control

**Description:**
5.1 Problem statement.
5.2 Hamiltonian.
5.3 Pontryagin’s minimum principle (PMP).
5.4 Property of the Hamiltonian.

**Learning time:** 8h
- Theory classes: 3h
- Self study: 5h

### 6. Linear quadratic problem (LQP)

**Description:**
6.1 Linear quadratic problems.
6.2 Riccati equations.
6.3 Examples.

**Learning time:** 6h
- Theory classes: 2h
- Self study: 4h

### 7. Pontryagin’s Minimum Principle. Piecewise continuous control

**Description:**
The time-optimal control.

**Learning time:** 8h
- Theory classes: 3h
- Self study: 5h

### 8. MATLAB Simulation (first part)

**Description:**
8.1 Introduction.
8.2 MATLAB as advanced calculator.
8.3 Scripts and functions.
8.4 Vectors and matrices.
8.5 The ode45 MATLAB function.
8.6 Optimization.

**Learning time:** 24h
- Laboratory classes: 16h
- Self study: 8h
Planning of activities

<table>
<thead>
<tr>
<th>A1: THEORY EXAM (SUBJECTS 2, 3, 4, 5, 6, AND 7)</th>
<th>A2: LABORATORY EXAM WITH MATLAB (SUBJECT 8 AND 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hours</strong>: 8h</td>
<td><strong>Hours</strong>: 4h</td>
</tr>
<tr>
<td>Guided activities: 2h</td>
<td>Guided activities: 2h</td>
</tr>
<tr>
<td>Self study: 6h</td>
<td>Self study: 2h</td>
</tr>
</tbody>
</table>

Qualification system

Final grade will be

30% A2 and 70% A1.

A1 is the only re-gradable activity.

Regulations for carrying out activities

The conditions for carrying out the written exams will be announced in each case in due time.

Bibliography

**Basic:**

