# 34955 - COMB - Combinatorics

**Coordinating unit:** 200 - FME - School of Mathematics and Statistics  
**Teaching unit:** 749 - MAT - Department of Mathematics  
**Academic year:** 2019  
**Degree:** MASTER'S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)  
**ECTS credits:** 7.5  
**Teaching languages:** English

## Teaching staff

**Coordinator:** ORIOL SERRA ALBO  
**Others:** Segon quadrimestre:  
- JUAN JOSÉ RUE PERNA - A  
- ORIOL SERRA ALBO - A

## Prior skills

Basic calculus and linear algebra. Notions of probability.

## Degree competences to which the subject contributes

### Specific:
1. **RESEARCH.** Read and understand advanced mathematical papers. Use mathematical research techniques to produce and transmit new results.
2. **CALCULUS.** Obtain (exact or approximate) solutions for these models with the available resources, including computational means.
3. **CRITICAL ASSESSMENT.** Discuss the validity, scope and relevance of these solutions; present results and defend conclusions.

### Transversal:
4. **SELF-DIRECTED LEARNING.** Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.
5. **EFFICIENT ORAL AND WRITTEN COMMUNICATION.** Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.
6. **THIRD LANGUAGE.** Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.
7. **TEAMWORK.** Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
8. **EFFECTIVE USE OF INFORMATION RESOURCES.** Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.

## Teaching methodology

There will be a lecture each week, followed by a problem session.

## Learning objectives of the subject

To use algebraic, probabilistic and analytic methods for studying combinatorial structures. The main topics of study are:
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partially ordered sets, extremal set theory, finite geometries, matroids, Ramsey theory and enumerative combinatorics.

**Study load**

<table>
<thead>
<tr>
<th></th>
<th>Hours large group:</th>
<th>Self study:</th>
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<tbody>
<tr>
<td><strong>Total learning time:</strong></td>
<td>187h 30m</td>
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<tr>
<td></td>
<td>60h</td>
<td>127h 30m</td>
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<td>32.00%</td>
<td>68.00%</td>
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### Content

<table>
<thead>
<tr>
<th>Partially ordered sets</th>
<th><strong>Learning time:</strong> 24h 40m</th>
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</thead>
<tbody>
<tr>
<td></td>
<td><strong>Practical classes:</strong> 4h</td>
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<tr>
<td></td>
<td><strong>Laboratory classes:</strong> 4h</td>
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<tr>
<td></td>
<td><strong>Self study:</strong> 16h 40m</td>
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**Description:**
Sperner's theorem. LYM inequalities. Bollobás's theorem. Dilworth's theorem

<table>
<thead>
<tr>
<th>Extremal set theory</th>
<th><strong>Learning time:</strong> 24h 40m</th>
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<tbody>
<tr>
<td></td>
<td><strong>Theory classes:</strong> 4h</td>
</tr>
<tr>
<td></td>
<td><strong>Laboratory classes:</strong> 4h</td>
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<tr>
<td></td>
<td><strong>Self study:</strong> 16h 40m</td>
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**Description:**
Theorems of Baranyai, Erdos-de Bruijn and Erdos-Ko-Rado

<table>
<thead>
<tr>
<th>Linear algebra methods in combinatorics</th>
<th><strong>Learning time:</strong> 18h 30m</th>
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<tbody>
<tr>
<td></td>
<td><strong>Theory classes:</strong> 3h</td>
</tr>
<tr>
<td></td>
<td><strong>Laboratory classes:</strong> 3h</td>
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<td></td>
<td><strong>Self study:</strong> 12h 30m</td>
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**Description:**
The polynomial method and applications. Fisher's theorem. Equiangular lines, sets with few differences

<table>
<thead>
<tr>
<th>Finite geometries</th>
<th><strong>Learning time:</strong> 18h 30m</th>
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<tbody>
<tr>
<td></td>
<td><strong>Theory classes:</strong> 3h</td>
</tr>
<tr>
<td></td>
<td><strong>Laboratory classes:</strong> 3h</td>
</tr>
<tr>
<td></td>
<td><strong>Self study:</strong> 12h 30m</td>
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</tbody>
</table>

**Description:**
### Matroids

**Learning time:** 18h 30m  
Theory classes: 3h  
Laboratory classes: 3h  
Self study: 12h 30m

**Description:**  
Axioms. Transversal matroids. Greedy algorithms. The Tutte polynomial

### Probabilistic methods in combinatorics

**Learning time:** 18h 30m  
Theory classes: 3h  
Laboratory classes: 3h  
Self study: 12h 30m

**Description:**  
Permanents, transversals, hypergraph coloring. Monotone properties and threshold functions

### Ramsey theory

**Learning time:** 31h 40m  
Theory classes: 5h  
Laboratory classes: 5h  
Self study: 21h 40m

**Description:**  
Theorems of Ramsey and Hales-Jewett. Theorems of Schur, Van der Waerden and Rado.

### Enumerative combinatorics

**Learning time:** 32h 30m  
Theory classes: 5h  
Laboratory classes: 5h  
Self study: 22h 30m

**Description:**  
Symbolic and analytic methods. Symmetries and Pólya theory.

### Qualification system

Grading will be based on the solution of exercises. Eventually there will be a final examination.
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Bibliography

Basic: