34955 - COMB - Combinatorics

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 749 - MAT - Department of Mathematics
Academic year: 2018
Degree: MASTER’S DEGREE IN ADVANCED MATHEMATICS AND MATHEMATICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 7,5

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:
34955 - COMB - Combinatorics

partially ordered sets, extremal set theory, finite geometries, matroids, Ramsey theory and enumerative combinatorics.

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

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time: 24h 40m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partially ordered sets</strong></td>
<td>4h Theory classes:</td>
</tr>
<tr>
<td></td>
<td>4h Laboratory classes:</td>
</tr>
<tr>
<td></td>
<td>16h 40m Self study:</td>
</tr>
</tbody>
</table>

**Description:**
- Sperner’s theorem
- LYM inequalities
- Bollobás's theorem
- Dilworth's theorem

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time: 24h 40m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extremal set theory</strong></td>
<td>4h Theory classes:</td>
</tr>
<tr>
<td></td>
<td>4h Laboratory classes:</td>
</tr>
<tr>
<td></td>
<td>16h 40m Self study:</td>
</tr>
</tbody>
</table>

**Description:**
- Theorems of Baranyai, Erdos-de Bruijn and Erdos-Ko-Rado

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time: 18h 30m</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Linear algebra methods in combinatorics</strong></td>
<td>3h Theory classes:</td>
</tr>
<tr>
<td></td>
<td>3h Laboratory classes:</td>
</tr>
<tr>
<td></td>
<td>12h 30m Self study:</td>
</tr>
</tbody>
</table>

**Description:**
- The polynomial method and applications
- Fisher's theorem
- Equiangular lines, sets with few differences

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

**Description:**
- q-analogs of extremal problems
- Segre's theorem
- Blocking sets, ovals and hyperovals
### 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.
# Bibliography

## Basic:


