240619 - Nuclear Fusion. Iter

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 748 - FIS - Department of Physics
Academic year: 2018
Degree: BACHELOR'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2010). (Teaching unit Optional)
BACHELOR'S DEGREE IN MATERIALS ENGINEERING (Syllabus 2010). (Teaching unit Optional)
BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 4,5
Teaching languages: English

Teaching staff
Coordinator: ALFREDO DE BLAS DEL HOYO
Others: Blas Del Hoyo, Alfredo De Cortes Rossell, Guillem Pere

Degree competences to which the subject contributes

Transversal:
1. 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.
2. SUSTAINABILITY AND SOCIAL COMMITMENT. Being aware of and understanding the complexity of social and economic phenomena that characterize the welfare society. Having the ability to relate welfare to globalization and sustainability. Being able to make a balanced use of techniques, technology, the economy and sustainability.
Teaching methodology

1. LECTURES AND CASE EXAMPLES.
Lectures are devoted to form the content of the subject, and some case examples enable to retain and quantify the presented concepts.
These lecture sessions are supported by slides that graphically complement the main ideas of the presentations. Previous nesses to that, the slides are distributed to the students, making easy to follow the explanations. The "Digital Campus" will be used throughout the course.

2. MULTIMEDIA RESOURCES.
Some technological aspects of the subject are complemented by multimedia projections:
- Magnetic confinement Fusion.
- Tore Supra. (Superconducting materials used in this experimental fusion device).
- JET, Joint European Torus.

3. LAB WORK.
The following lab work has been prepared with the aim of motivating the student:
- Use of a Nuclear Fusion Reactor Simulator type Tokamak for educational purposes.
The students individually will simulate the following cases:
  P1. Reproduction of actual experiences of fusion devices (JET, Tore Supra).
  P2. ITER fusion reactor operation simulation.

Methodology for the development of the lab work:
- Presentation of the software: content, models included, and data base required.
- Running of the simulation program: definition of input parameters and data, output data and storage.
- Analysis of the results.
- Guidance for the answers of the stated questions, and report elaboration.

4. TECHNICAL VISIT.
Technical visit to the reactor Tore Supra and the ITER site in CEA, France:
-Tore Supra is a thermonuclear fusion reactor type Tokamak, builded in 1989. The toroidal magnetic fields are created by using superconducting coils. The reactor is operated by the "Departament de Recherches sur la Fusion Contrôlée", of the "Commissariat d'Energie Atomique", "Association EURATOM-CEA sur la fusion", Cadarache France.
http://www-cad.cea.fr
-Visit the ITER site in Cadarache, France. This is a thermonuclear reactor of 500 MW of nominal power, is a tokamak reactor. The coils are superconducting. The budget is more than 10.000 M€. This is the second biggest international project in the world. With the participation of: EEUU, Japón, Europa, China, Rusia, Corea, and India.
http://www.iter.org
(7 hours + travel)
A special relevance is given to technological aspects related to the different heating and cooling methods as the Neutral Beam Injection (NBI), Radio Frequency (RF) heating systems, cryogenic systems, electrical systems for the generation of magnetic fields, and plasma diagnostics.

Learning objectives of the subject

At the end of the course the student will be able to:
a) To know the basic physics necessary in order to understand the development of nuclear fusion energy.
b) To provide the state of art of the different technological ways towards the achievement of a commercial fusion reactor.
c) To understand the technological aspects required for the fusion energy production.
d) To applied the elemental background and tools for performance evaluations and calculations.
e) To know the ITER project, the technological aspects, the objectives, and the construction schedule.
### Study load

<table>
<thead>
<tr>
<th>Study load</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total learning time:</strong> 112h 30m</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td>Hours large group:</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td>Hours medium group:</td>
<td>45h</td>
<td>40.00%</td>
</tr>
<tr>
<td>Hours small group:</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td>Guided activities:</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td>Self study:</td>
<td>67h 30m</td>
<td>60.00%</td>
</tr>
</tbody>
</table>
# 240619 - Nuclear Fusion. Iter

## Content

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Learning time</th>
<th>Theory classes</th>
</tr>
</thead>
</table>
| 1. Introduction | 1. Energy Resources.  
2. Fusion Reactions.  
3. Fuels.  
4. Fusion products.  
5. Thermonuclear fusion history. | 1h 30m | 1h 30m |
<p>| 2. Introduction to nuclear physics | description: content english | 3h | 3h |
| 3. Fusion energy | description: content english | 3h | 3h |
| 4. Power balance | description: content english | 3h | 3h |
| 5. Approximation to a fusion reactor | description: content english | 1h | 1h |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
</table>
| **6. Plasma definition** | **Learning time:** 3h  
 theory classes: 3h |
| **Description:** | content english |
| **7. Behaviour of a particle inside the plasma** | **Learning time:** 6h  
 theory classes: 3h  
 self study: 3h |
| **Description:** | content english |
| **8. Diffusion and collisions. Resistivity of plasma** | **Learning time:** 6h  
 theory classes: 3h  
 self study: 3h |
| **Description:** | content english |
| **9. MHD models. Equilibrium and stability** | **Learning time:** 6h  
 theory classes: 3h  
 self study: 3h |
| **Description:** | content english |
| **10. Plasma-wall interaction** | **Learning time:** 1h 30m  
 theory classes: 1h 30m |
| **Description:** | content english |
### 11. Plasma Heating

**Learning time:** 1h 30m  
Theory classes: 1h 30m  

**Description:**  
content english

### 12. Plasma Diagnostics

**Learning time:** 1h 30m  
Theory classes: 1h 30m  

**Description:**  
content english

### 13. Stellarators

**Learning time:** 1h 30m  
Theory classes: 1h 30m  

**Description:**  
content english
# Planning of activities

## (ENG) USE OF A NUCLEAR FUSION REACTOR SIMULATOR TYPE TOKAMAK FOR EDUCATIONAL PURPOSES.

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>The students individually will simulate the following cases:</td>
</tr>
<tr>
<td>P1. Reproduction of actual experiences of fusion devices (JET, Tore Supra).</td>
</tr>
<tr>
<td>P2. ITER fusion reactor operation simulation.</td>
</tr>
</tbody>
</table>

**Methodology for the development of the lab work:**
- Presentation of the software: content, models included, and data base required.
- Running of the simulation program: definition of input parameters and data, output data and storage.
- Analysis of the results.
- Guidance for the answers of the stated questions, and report elaboration.

**Descriptions of the assignments due and their relation to the assessment:**
If the reports related to this experiences are delivered a positive valuation is done.

<table>
<thead>
<tr>
<th>Hours: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory classes: 4h</td>
</tr>
<tr>
<td>Self study: 12h</td>
</tr>
</tbody>
</table>

## (ENG) TECHNICAL VISIT TO ITER AND TO TORE SUPRA (CADARACHE, FRANCE)

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical visit to the reactor Tore Supra and the ITER site in CEA, France:</td>
</tr>
<tr>
<td>-Tore Supra is a thermonuclear fusion reactor type Tokamak, builded in 1989. The toroidal magnetic fields are created by using superconducting coils. The reactor is operated by the &quot;Département de Recherches sur la Fusion Contrôlée&quot;, of the &quot;Commissariat d'Energie Atomique&quot;, &quot;Association EURATOM-CEA sur la fusion&quot;, Cadarache France.</td>
</tr>
<tr>
<td><a href="http://www-cad.cea.fr">http://www-cad.cea.fr</a></td>
</tr>
<tr>
<td>-Visit the ITER site in Cadarache, France. This is a thermonuclear reactor of 500 MW of nominal power, is a tokamak reactor. The coils are superconducting. The budget is more than 10.000 M€. This is the second biggest international project in the world. With the participation of: EEUU, Japón, Europa, China, Rusia, Corea, and India. <a href="http://www.iter.org">http://www.iter.org</a></td>
</tr>
<tr>
<td>(7 hours + travel)</td>
</tr>
<tr>
<td>A special relevance is given to technological aspects related to the different heating and cooling methods as the Neutral Beam Injection (NBI), Radio Frequency (RF) heating systems, cryogenic systems, electrical systems for the generation of magnetic fields, and plasma diagnostics.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hours: 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory classes: 6h</td>
</tr>
</tbody>
</table>
Qualification system

The student performance is performed assigning a weight of 40% to the continuous learning (exercises and practices) and a weight of 60% to theoretical and technical concepts (nuclear fusion, plasma physics and nuclear fusion technology). The evaluation of the theoretical topics is realized in two exams. In the first exam covers the nuclear fusion and plasma physics topics. The second exam covers the fusion technology topics ans the recovery of the first.

The qualification of practical sessions is based on the reports from the students in each sessions. The exercises evaluation is based on the delivering of the students. These exercises are performed in the classroom with the help of the professor. The final qualification is:

\[ NF = 0.2 \times NE + 0.2 \times NP + 0.4 \times N1 + 0.2 \times N2 \]

\( NF \) = Final grade

\( N1 \) = Grade of nuclear plasma and nuclear fusion

\( N2 \) = Grade of nuclear fusion technology

\( NP \) = Practices grade

\( NE \) = Exercises grade.

Regulations for carrying out activities

The evaluations will be questions with development, without notes.

Bibliography

Basic:


Complementary: