240NU216 - Instrumentation

Coordinating unit: 240 - ETSEIB - Barcelona School of Industrial Engineering
Teaching unit: 748 - FIS - Department of Physics
Academic year: 2017
Degree: MASTER'S DEGREE IN NUCLEAR ENGINEERING (Syllabus 2012). (Teaching unit Optional)
ECTS credits: 4.5
Teaching languages: English

Teaching staff
Coordinator: ALFREDO DE BLAS DEL HOYO
Others: YOURI ALEXANDROVICH KOUBYCHINE MERKULOV

Opening hours
Timetable: To be determined with the professor

Degree competences to which the subject contributes

Specific:
3. Ability to use ionizing radiation detectors, appropriate to the required application, together with the associated instrumentation.

General:
1. Ability to design, calculate and design processes, equipment, facilities and plants related to the procurement of nuclear energy and the use of ionizing radiation.
2. Have adequate knowledge of mathematical aspects, analytical, scientific, instrumental, technological and management.
Teaching methodology

This subject combines experimental sessions, simulations and lectures to introduce the basic information.

MD.2 Lectures

The professor introduces the basic information of the various sections.

MD.3 Scheduled independent learning

Throughout the course, students must solve some selected exercises, research some topics on the specialized literature and perform some simulations of the instrumentation and the detectors to analyse the systems and its operations.

MD.4 Cooperative Learning

Resolution in the class of some system analysis that requires the complete collaboration of all the members of the working group

During the course, a specific number of experimental practices will be carried out in the laboratory. Each practice has a pre-laboratory task, and the redaction of a report with some post-laboratory and analysis tasks is mandatory.

MD.5 Project Based Learning

Throughout the course, students must design a detection system with the proper instrumentation to solve a specific problem raised at the beginning of the course.

Learning objectives of the subject

1. Explain the electric equivalent circuit of a detector
2. Quantify the influence of the impedance of the terminals of the detector
3. Explain the influence of the transmission line on an instrumentation system
4. Identify the factors due to the instrumentation and the detector that influences on the resolution
5. Explain how the signal is shaped to improve the resolution of the detection system
6. Describe the operation of the basic nuclear instrumentation modules (preamplifier, pulse amplifier, single channel analyzer, multiple channel analyzer and small current amplifiers)
7. Select the most suitable modules of nuclear instrumentation for each application
8. Determine the error associated to the stochastic nature of the radiation, using the most adequate statistic model and the error transmission formula
9. Determine the minimum activity detectable by a detection system
10. Determine if a measurement is due to a radioactive source or it is background
11. Interpret and analyze the spectrum of a gamma spectrometry
12. Select the best detector for a spectrometry as function of the application
13. Calibrate on efficiency and energy a gamma spectrometry system.
14. Determine the activity and identify the emitters on a gamma spectrometry
15. Interpret the problems of the detection on low count rate systems and which solutions must be performed to asses an accurate measurement
16. Analyze the sources of background.
17. Design the shielding of a detection system to reduce the background component of the measurement
18. Describe the coincidence and anti-coincidence techniques and its applications
19. Explain how the exposition and dose can be determined on a detector
20. Interpret the problems of the detection on high count rate systems and which solutions must be performed to asses an accurate measurement
21. Explain the detection of slow neutrons with gas-filled detectors
22. Explain the most important methods of fast neutrons detection
23. Describe the operation some special neutron detectors used on nuclear reactor instrumentation
24. Design a detection system with the associated instrumentation for an specific application

<table>
<thead>
<tr>
<th>Study load</th>
<th>Hours large group:</th>
<th>0h</th>
<th>0.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total learning time: 112h 30m</td>
<td>Hours medium group:</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Hours small group:</td>
<td>40h 30m</td>
<td>36.00%</td>
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<tr>
<td></td>
<td>Guided activities:</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Self study:</td>
<td>72h</td>
<td>64.00%</td>
</tr>
</tbody>
</table>
## Content

<table>
<thead>
<tr>
<th>Section</th>
<th>Learning time</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Introduction</strong></td>
<td>1h</td>
<td>content english</td>
</tr>
<tr>
<td><strong>2. General concepts of instrumentation</strong></td>
<td>2h</td>
<td>content english</td>
</tr>
<tr>
<td><strong>3. Noise and interferences</strong></td>
<td>2h 30m</td>
<td>content english</td>
</tr>
<tr>
<td><strong>4. Signal transmission</strong></td>
<td>2h 30m</td>
<td>content english</td>
</tr>
<tr>
<td><strong>5. Preamplifiers</strong></td>
<td>2h</td>
<td>content english</td>
</tr>
</tbody>
</table>
6. Analogic shaping of pulses | **Learning time:** 3h  
Theory classes: 1h  
Practical classes: 1h  
Laboratory classes: 1h

**Description:**  
content english

7. Pulse counting and height analysis | **Learning time:** 1h  
Theory classes: 1h

**Description:**  
content english

8. Signal acquisition. Sampling | **Learning time:** 2h  
Theory classes: 2h

**Description:**  
content english

9. Digital filters | **Learning time:** 2h  
Theory classes: 2h

**Description:**  
content english

10. Small current measurement | **Learning time:** 2h  
Theory classes: 1h  
Laboratory classes: 1h

**Description:**  
content english
## 11. Statistics for radiation detection

**Description:**
content english

**Learning time:** 2h  
Theory classes: 1h  
Practical classes: 1h

## 12. Gas filled detectors

**Description:**
content english

**Learning time:** 2h  
Theory classes: 1h  
Practical classes: 1h

## 13. Scintillators

**Description:**
content english

**Learning time:** 2h  
Theory classes: 1h  
Practical classes: 1h

## 14. Semiconductors

**Description:**
content english

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

## 15. Detector analysis as trasnducers

**Description:**
content english

**Learning time:** 2h  
Theory classes: 1h  
Practical classes: 1h

**Description:**
content english

**Learning time:** 2h
- Theory classes: 1h
- Practical classes: 1h

### 17. Project and laboratory experiences

**Description:**
content english

**Learning time:** 10h
- Guided activities: 10h
# Planning of activities

## THEORY
- **Description:** At class, the teacher introduces the concepts in order to give to the students the capacity to develop the objectives of the subject.
- **Support materials:** Oral presentations with the support of projectors. The presentation will be previously submitted to the students using the virtual campus.
- **Specific objectives:** 1-20
- **Hours:** 55h
  - Laboratory classes: 31h
  - Self study: 24h

## RESOLUTION OF PROBLEMS
- **Description:** Problems presented and discussed at class.
- **Descriptions of the assignments due and their relation to the assessment:** Extra time to work at home and finish the problem.
- **Specific objectives:** 1-3, 14, 16, 19
- **Hours:** 8h
  - Laboratory classes: 8h

## INSTRUMENTATION SIMULATION
- **Description:** The student analyzes the operation of the instrumentation modules presented at class, with electric circuit simulation tools.
- **Support materials:** PSPICE student version
- **Descriptions of the assignments due and their relation to the assessment:** A report for each analysis is delivered
- **Specific objectives:** 10
- **Hours:** 9h
  - Laboratory classes: 1h
  - Self study: 8h

## PRACTICAL SESSIONS
- **Hours:** 42h
  - Laboratory classes: 14h
  - Self study: 28h
# 240NU216 - Instrumentation

**Description:**
Seven experimental practices on the Detection and Nuclear Instrumentation Laboratory of the Nuclear Engineering Section

**Support materials:**
The equipment of the Detection and Nuclear Instrumentation Laboratory. A guide for each session will be previously submitted to the students using the virtual campus.

**Descriptions of the assignments due and their relation to the assessment:**
A report for each experimental practice is delivered

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## COURSE PROJECT

<table>
<thead>
<tr>
<th>Description:</th>
<th>Hours: 15h</th>
</tr>
</thead>
<tbody>
<tr>
<td>The design of a detection system for a determined application will be developed during the course. This design will be done in groups of three students.</td>
<td>Self study: 15h</td>
</tr>
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</table>

**Descriptions of the assignments due and their relation to the assessment:**
Report at the end of the trimester

**Specific objectives:**
21

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## SIMULATION OF DETECTORS

<table>
<thead>
<tr>
<th>Description:</th>
<th>Hours: 4h</th>
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</table>
| When the course project design allows it, the working group will use a Montecarlo code to analyze the detection system (i.e efficiency determination). When the design doesn't allow it, the teacher will propose a detection system to perform the analysis. | Laboratory classes: 2h
Self study: 2h |

**Support materials:**
Montecarlo code

**Descriptions of the assignments due and their relation to the assessment:**
Report at the end of the trimester

**Specific objectives:**
22

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## EVALUATION ACTIVITIES

<table>
<thead>
<tr>
<th>Description:</th>
<th>Hours: 3h</th>
</tr>
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<tbody>
<tr>
<td>Two exams will be carried out: 1. Section 1 to 3 of the Course description 2. Section 4 to 8 of the Course description</td>
<td>Laboratory classes: 3h</td>
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</tbody>
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Qualification system

IE.1 Exam

Individual exam in the classroom of, approximately 2h, with a theoretical part carried out without any information and a second part, where a system analysis is make with the information that the student considers pertinent.

IE.2 Analysis, simulations...

During the course students, gathered in working groups, will analyse instrumentation systems and will simulate diverse modules of instrumentation.

Apart from this, students will develop a project consisting of the design of a detection system for a determinate application.

IE.3. Reports

Each working group delivers a report for each laboratory experiment. In the report the students show the results of the experiments, indicate the incidences that might have occurred during the experiment and analyse the results.

The final mark is determined by the following expression:

FINAL MARK: \( FM = 0.1 \times E + 0.2 \times T + 0.4 \times L + 0.3 \times P \)

\( E = \) Exercises and simulations
\( T = \) Exam
\( L = \) Laboratory
\( P = \) Project

Bibliography

Basic: