



POLITÉCNICA

INTERNATIONAL  
CAMPUS OF  
EXCELLENCE

COORDINATION PROCESS OF  
LEARNING ACTIVITIES  
PR/CL/001



E.T.S. de Ingenieros  
Industriales

# ANX-PR/CL/001-01

## LEARNING GUIDE

### SUBJECT

**53002040 - Monte Carlo Simulation For Nuclear Analysis**

### DEGREE PROGRAMME

05BK - Máster Universitario En Ingeniería De La Energía

### ACADEMIC YEAR & SEMESTER

2025/26 - Semester 2

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### Learning guide

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## 1. Description

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### 1.1. Subject details

|                                       |   |
|---------------------------------------|---|
| <b>Name of the subject</b>            | 53002040 - Monte Carlo Simulation For Nuclear Analysis  |
| <b>No of credits</b>                  | 3 ECTS  |
| <b>Type</b>                           | Optional/elective                                       |
| <b>Academic year of the programme</b> | First year  |
| <b>Semester of tuition</b>            | Semester 2  |
| <b>Tuition period</b>                 | February-June   |
| <b>Tuition languages</b>              | English   |
| <b>Degree programme</b>               | 05BK - Máster Universitario en Ingeniería de la Energía |
| <b>Centre</b>                         | 05 - E.T.S. De Ingenieros Industriales                  |
| <b>Academic year</b>                  | 2025-26   |

## 2. Faculty

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### 2.1. Faculty members with subject teaching role

| <b>Name and surname</b>                       | <b>Office/Room</b> | <b>Email</b>                    | <b>Tutoring hours *</b>                             |
|---|--------------------|---------------------------------|---|
| Gonzalo Felipe Garcia<br>Fernandez            | Nuclear<br>Planta1 | gf.garcia@upm.es                | Sin horario.<br>Solicitar por correo<br>electrónico |
| Nuria Garcia Herranz<br>(Subject coordinator) | Nuclear<br>Planta1 | nuria.garcia.herranz@upm.e<br>s | Sin horario.<br>Solicitar por correo<br>electrónico |

|                        |                    |                      |   |
|------------------------|--------------------|----------------------|---|
| Emilio Castro Gonzalez | Nuclear<br>Planta1 | emilio.castro@upm.es | Sin horario.<br>Solicitar por correo<br>electrónico |
|------------------------|--------------------|----------------------|---|

\* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

### 3. Prior knowledge recommended to take the subject

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#### 3.1. Recommended (passed) subjects

- Fundamentos De Energía Nuclear

#### 3.2. Other recommended learning outcomes

- Tecnología nuclear: fundamentos de las desintegraciones, reacciones nucleares, ciclo neutrónico en reactores de fisión

- Centrales nucleares

### 4. Skills and learning outcomes \*

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#### 4.1. Skills to be learned

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

CE14 - Ser capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios, en el tratamiento y almacenamiento de los residuos radiactivos generados en instalaciones nucleares y radiactivas, incluyendo reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios.

CE15 - Conocer los criterios básicos de seguridad y protección radiológica, el impacto de las radiaciones ionizantes y las tecnologías del blindaje contra las mismas.

CE3 - Utilizar las herramientas necesarias para el diseño y análisis de sistemas de generación, transformación, almacenamiento y utilización de energías nucleares, mecánicas, eléctricas, térmicas e hidráulicas.

CG1 - Aplicar conocimientos de ciencias y tecnologías avanzadas a la práctica profesional o investigadora de la

Ingeniería Energética.

CG2 - Poseer capacidad para diseñar, desarrollar, implementar, gestionar y mejorar productos, sistemas y procesos en los distintos ámbitos energéticos, usando técnicas analíticas, computacionales o experimentales avanzadas.

CG8 - Incorporar nuevas tecnologías y herramientas avanzadas de la Ingeniería Energética en sus actividades profesionales o investigadoras.

CT11 - Usa herramientas. Habilidad para usar las técnicas, destrezas y herramientas ingenieriles modernas necesarias para la práctica de la ingeniería.

CT12 - Es bilingüe. Capacidad de trabajar en un entorno bilingüe (inglés/español).

CT3 - Diseña. Habilidad para diseñar un sistema, componente o proceso que alcance los requisitos deseados teniendo en cuenta restricciones realistas tales como las económicas, medioambientales, sociales, políticas, éticas, de salud y seguridad, de fabricación y de sostenibilidad.

CT5 - Resuelve. Habilidad para identificar, formular y resolver problemas de ingeniería.

CT7 - Comunica. Habilidad para comunicar eficazmente.

## 4.2. Learning outcomes

RA68 - Destreza en la utilización de herramientas de simulación para diseño y análisis de sistemas nucleares

RA66 - Saber evaluar un sistema desde el punto de vista de la criticidad y radioprotección

RA67 - Saber realizar el diseño y análisis de reactores nucleares de fisión

\* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

## 5. Brief description of the subject and syllabus

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### 5.1. Brief description of the subject

Monte Carlo methods are stochastic techniques to solve problems through numerical simulations using sequences of random numbers. Nowadays, those methods are widely used in different fields of physics and engineering, from astrophysics to nuclear medicine. In particular, in the nuclear industry, those methods are the only ones capable of providing detailed solutions of the radiation transport in complex systems.

The purpose of this course is to introduce students to the use of Monte Carlo transport codes for the design and analysis of radioactive and nuclear facilities. Monte Carlo simulations provide reference solutions in reactor physics, in radiological protection studies (doses and shielding) or in criticality safety assessments when handling fissile materials in facilities other than nuclear reactors (in both the front-end and the back-end of the fuel cycle). The course will consist of theoretical lectures and hands-on sessions using the Monte Carlo neutron transport code OpenMC.

The course topics are focused on neutron transport but the covered methods also apply to other radiation transport problems.

After this course, students should:

- Master the theory behind the Monte Carlo simulation of radiation transport in fissile systems and non-fissile systems with an external source, interpreting and evaluating the results of statistical nature
- Know how to model a system and which data are required for a transport Monte Carlo simulation

## 5.2. Syllabus

1. Fundamentals of Monte Carlo methods
  - 1.1. Basic principles
  - 1.2. Random number generation
  - 1.3. Sampling procedures
  - 1.4. Error estimation
  - 1.5. Application to the neutron transport
2. Monte Carlo neutron transport code
  - 2.1. Geometry
  - 2.2. Materials and nuclear data libraries
  - 2.3. Eigenvalue problems (criticality) and fixed source problems (shielding)
  - 2.4. Tallying procedures
  - 2.5. Analog and non-analog Monte Carlo methods: variance reduction techniques
3. Application to the design and analysis of nuclear systems (steady-state neutron calculations)
  - 3.1. Application to criticality safety analysis in the front- and back-end nuclear fuel cycle
  - 3.2. Application to reactor physics (pin-cell design, fuel assembly design, core design)
  - 3.3. Application to shielding calculations
  - 3.4. Application to other systems (e.g. accelerator-driven subcritical systems)

## 6. Schedule

### 6.1. Subject schedule\*

| Week | Type 1 activities   | Type 2 activities | Distant / On-line | Assessment activities   |
|------|---|-------------------|-------------------|---|
| 1    | <b>Impartición Tema 1</b><br>Duration: 02:00<br>Lecture                             |                   |                   |   |
| 2    | <b>Ejercicios de simulación Tema 1</b><br>Duration: 02:00<br>Cooperative activities |                   |                   |   |
| 3    | <b>Ejercicios de simulación Tema 1</b><br>Duration: 02:00<br>Cooperative activities |                   |                   |   |
| 4    | <b>Ejercicios de simulación Tema 1</b><br>Duration: 02:00<br>Cooperative activities |                   |                   |   |
| 5    | <b>Impartición Tema 2</b><br>Duration: 02:00<br>Lecture                             |                   |                   | <b>Entrega Cuaderno Electrónico correspondiente a Ejercicios Tema 1</b><br>Individual work<br>Progressive assessment<br>Not Presential<br>Duration: 00:00 |
| 6    | <b>Ejercicios de simulación Tema 2</b><br>Duration: 02:00<br>Cooperative activities |                   |                   |   |
| 7    | <b>Ejercicios de simulación Tema 2</b><br>Duration: 02:00<br>Cooperative activities |                   |                   |   |
| 8    | <b>Ejercicios de simulación Tema 2</b><br>Duration: 02:00<br>Cooperative activities |                   |                   |   |
| 9    | <b>Ejercicios de simulación Tema 2</b><br>Duration: 02:00<br>Cooperative activities |                   |                   |   |
| 10   | <b>Impartición Tema 3</b><br>Duration: 02:00<br>Lecture                             |                   |                   |   |
| 11   | <b>Ejercicios de simulación Tema 3</b><br>Duration: 02:00<br>Cooperative activities |                   |                   | <b>Entrega Cuaderno Electrónico correspondiente a Ejercicios Tema 2</b><br>Individual work<br>Progressive assessment<br>Not Presential<br>Duration: 00:00 |
| 12   | <b>Trabajo de aplicación Tema 3</b><br>Duration: 02:00<br>Cooperative activities    |                   |                   | <b>Entrega trabajo realizado (correspondiente al Tema 3)</b><br>Group presentation<br>Progressive assessment<br>Not Presential<br>Duration: 00:00         |

|    |   |  |  |   |
|----|---|--|--|---|
| 13 | Trabajo de aplicación Tema 3<br>Duration: 02:00<br>Cooperative activities |  |  |   |
| 14 |   |  |  | <b>Presentación trabajo realizado (correspondiente al Tema 3)</b><br>Group presentation<br>Progressive assessment<br>Presential<br>Duration: 02:00  |
| 15 |   |  |  |   |
| 16 |   |  |  |   |
| 17 |   |  |  | <b>Examen de evaluación continua</b><br>Written test<br>Progressive assessment<br>Presential<br>Duration: 01:00<br><br><b>Examen final- Parte teórica</b><br>Written test<br>Global examination<br>Presential<br>Duration: 01:00<br><br><b>Examen final - Parte práctica</b><br>Other assessment<br>Global examination<br>Presential<br>Duration: 01:00 |

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

## 7. Activities and assessment criteria

### 7.1. Assessment activities

#### 7.1.1. Assessment

| Week | Description  | Modality           | Type          | Duration | Weight | Minimum grade | Evaluated skills    |
|------|--|--------------------|---------------|----------|--------|---------------|---------------------|
| 5    | Entrega Cuaderno Electrónico correspondiente a Ejercicios Tema 1 | Individual work    | No Presential | 00:00    | 15%    | 5 / 10        | CG8<br>CE3<br>CT11  |
| 11   | Entrega Cuaderno Electrónico correspondiente a Ejercicios Tema 2 | Individual work    | No Presential | 00:00    | 15%    | 5 / 10        | CG8<br>CE3<br>CT11  |
| 12   | Entrega trabajo realizado (correspondiente al Tema 3)            | Group presentation | No Presential | 00:00    | 15%    | 5 / 10        | CT3<br>CE3<br>CT5   |
| 14   | Presentación trabajo realizado (correspondiente al Tema 3)       | Group presentation | Face-to-face  | 02:00    | 15%    | 5 / 10        | CT12<br>CT7<br>CE14 |
| 17   | Examen de evaluación continua                                    | Written test       | Face-to-face  | 01:00    | 40%    | 4 / 10        | CG1<br>CG2<br>CE15  |

#### 7.1.2. Global examination

| Week | Description                   | Modality         | Type         | Duration | Weight | Minimum grade | Evaluated skills                         |
|------|-------------------------------|------------------|--------------|----------|--------|---------------|--|
| 17   | Examen final- Parte teórica   | Written test     | Face-to-face | 01:00    | 40%    | 5 / 10        | CG1<br>CG2<br>CG8<br>CT3<br>CT11<br>CE15 |
| 17   | Examen final - Parte práctica | Other assessment | Face-to-face | 01:00    | 60%    | 5 / 10        | CE3<br>CT5<br>CT7<br>CT3<br>CT12<br>CE14 |

### 7.1.3. Referred (re-sit) examination

No se ha definido la evaluación extraordinaria.

## 7.2. Assessment criteria

Continuous evaluation (class attendance is mandatory)

Grading:

- 40% exam (points awarded should be > 4) on the day specified in the final exam schedule
- 30% individual assignments (to be solved in the classroom)
- 30% group project (3-4 students)

On the day of the exam, each group will make an oral presentation and will submit:

- Presentation
- OpenMC inputs (with proper use of commenting to ease understanding)

The presentation will include:

- Objectives: why the study carried out is of interest, what is intended to be calculated and for what
- Modeling with OpenMC (difficulties encountered, way to solve them, hypotheses made, . . . )
- Simulations carried out and discussion of the obtained results
- Conclusions
- Consulted bibliography

Grading will be based on the technical content of the presentation and demonstrated acquisition of knowledge; didactics for transmission of knowledge.

## Final examination

Grading:

- 40% theoretical exam
- 60% by solving a practical problem using a Monte Carlo code

## 8. Teaching resources

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### 8.1. Teaching resources for the subject

| Name   | Type         | Notes                             |
|--|--------------|-----------------------------------|
| Lecture notes on Moodle platform                                   | Bibliography |                                   |
| Monte Carlo Methods, M.H. Kalos and P.A. Whitlock, 2008            | Bibliography | Wiley-VCH                         |
| Monte Carlo Methods for Particle Transport, Alireza Haghghat, 2020 | Bibliography | CRC Press, Taylor & Francis Group |
| OpenMC Monte Carlo code Manual                                     | Web resource |                                   |
| EXCEL spreadsheet  | Others       |                                   |
| Simplified Monte Carlo code in FORTRAN                             | Others       |                                   |

## 9. Other information

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### 9.1. Other information about the subject

#### SUSTAINABLE DEVELOPMENT GOALS

The subject allows working on some of the Sustainable Development Goals such as:

**SDG 3 "Ensure healthy lives and promote well-being for all at all ages"**

## **SDG 9 "Build resilient infrastructure, promote sustainable industrialization and foster innovation"**

The subject works on these aspects by studying the basics of computational simulation tools that are essential today for the design and analysis of systems that use ionizing radiation, widely used in medicine and industrial applications.

## **SDG 17 "Revitalize the global partnership for sustainable development"**

Sustainable development cannot be achieved with the participation of a single organization or a single government. Partnerships are a key element in achieving the Sustainable Development Goals. The IAEA, the NEA and other international institutions have played an important role in the global agenda for sustainable development by helping countries use nuclear science to meet their development goals and working together. This aid consists of the exchange of knowledge through research projects, distribution of databases and software, technical cooperation projects, as well as the establishment of international guides and regulations.

These aspects are worked on in the course using nuclear databases and computer codes from international institutions.