ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

53002040 - SimulaciÓn De Monte Carlo Para AnÁlisis Nucleares

DEGREE PROGRAMME

05BK - Máster Universitario En Ingeniería De La Energía

ACADEMIC YEAR & SEMESTER

2023/24 - Semester 2

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1. Description

1.1. Subject details

Name of the subject	53002040 - Simulación de Monte Carlo para Análisis Nucleares
No of credits	3 ECTS
Type	Optional
Academic year ot the programme	First year
Semester of tuition	Semester 2
Tuition period	February-June
Tuition languages	English
Degree programme	05BK - Máster Universitario en Ingeniería de la Energía
Centre	05 - Escuela Técnica Superior De Ingenieros Industriales
Academic year	2023-24

2. Faculty

2.1. Faculty members with subject teaching role

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

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 *

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, trasformación, 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

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 MCNP.

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

13	**Trabajo de aplicación Tema 3** Duration: 02:00 Cooperative activities			
14				**Presentación trabajo realizado (correspondiente al Tema 3)** Group presentation Continuous assessment Presential Duration: 02:00
15				
16				
17				**Examen de evaluación continua** Written test Continuous assessment Presential Duration: 01:00 **Examen final- Parte teórica** Written test Final examination Presential Duration: 01:00 **Examen final - Parte práctica** Other assessment Final examination Presential 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.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

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 CE3 CT11
11	Entrega Cuaderno Electrónico correspondiente a Ejercicios Tema 2	Individual work	No Presential	00:00	15%	5 / 10	CG8 CE3 CT11
12	Entrega trabajo realizado (correspondiente al Tema 3)	Group presentation	No Presential	00:00	15%	5 / 10	CT3 CE3 CT5
14	Presentación trabajo realizado (correspondiente al Tema 3)	Group presentation	Face-to-face	02:00	15%	5 / 10	CT12 CT7 CE14
17	Examen de evaluación continua	Written test	Face-to-face	01:00	40%	4 / 10	CG1 CG2 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 CG2 CG8 CT3 CT11 CE15
17	Examen final - Parte práctica	Other assessment	Face-to-face	01:00	60%	5 / 10	CE3 CT5 CT7 CT3 CT12 CE14

7.1.3. Referred (re-sit) examination

No se ha definido la evaluación extraordinaria.

7.2. Assessment criteria

Continous 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
- MCNP 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 MCNP (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

8.1. Teaching resources for the subject

Name	Type	Notes
Lecture notes on Moodle platform	Bibliography	
Radiation transport with Monte Carlo methods applied to Radiological Protection	Bibliography	
Monte Carlo Methods, M.H. Kalos and P.A. Whitlock	Bibliography	
J.S. Hendricks, M.T. Swinhoe, A. Favalli, Monte Carlo N-Particle Simulations for Nuclear Detection and Safeguards, Springer, Open access, 2022, ISBN 978-3-031-04129-7	Bibliography	https://link.springer.com/content/pdf/10.1007/978-3-031-04129-7.pdf
MCNP Monte Carlo code Manual	Web resource	
EXCEL spreadsheet	Others	
Simplified Monte Carlo code in FORTRAN	Others	

9. Other information

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.