ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93001305 - Solar Cell Simulation Laboratory

DEGREE PROGRAMME

09BP - Master Universitario En Energia Solar Fotovoltaica

ACADEMIC YEAR & SEMESTER

2023/24 - Semester 2

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	93001305 - Solar Cell Simulation Laboratory
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	09BP - Master Universitario en Energia Solar Fotovoltaica
Centre	09 - Escuela Tecnica Superior De Ingenieros De Telecomunicacion
Academic year	2023-24

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
David Fuertes Marron (Subject coordinator)	IES 201	david.fuertes@upm.es	Tu - 15:00 - 16:00 with previous e-mail appoinmernt

* 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 CÉlulas Solares

3.2. Other recommended learning outcomes

The subject - other recommended learning outcomes, are not defined.

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.

CB6 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB7 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB8 - Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicios

CB9 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CE1 - Comprender, analizar y juzgar la relevancia de cualquier contribuciÃ³n en este campo, en relaciÃ³n con su entorno social, energÃ©tico y cientÃfico-tÃ©cnico.

CE2 - Conocimiento, anÃ¡lisis y propuestas de nuevos conceptos, mÃ©todos o dispositivos para la conversiÃ³n fotovoltaica.

CG5 - GestiÃ³n de la informaciÃ³n: buscar y gestionar recursos bibliogrÃ¡ficos adecuados con eficiencia, aprender a continuar los estudios de manera ampliamente autÃ³noma como base para la futura actividad de investigaciÃ³n e innovaciÃ³n

CG8 - Aplicar metodologÃas, procedimientos, herramientas y normas del estado del arte para la creaciÃ³n de nuevos componentes tecnolÃ³gicos; Construir nuevas hipÃ³tesis y modelos, evaluarlos y aplicarlos a la resoluciÃ³n de problemas

CG9 - Comunicar juicios, y conocimientos a audiencias especializadas y no especializadas, de una manera razonada, clara y sin ambigÃ¿edades

CT3 - Uso de la lengua inglesa: comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa; redactar en inglÃ©s informes y artÃculos cientÃfico-tÃ©cnicos usando herramientas informÃ¡ticas; realizar exposiciones pÃºblicas en inglÃ©s de trabajos, resultados y conclusiones de investigaciÃ³n, por ejemplo, en las asignaturas del MÃ¡ster o en congresos de carÃ¡cter mayoritariamente internacional o en estancias en centros extranjeros, todo ello con la ayuda de medios informÃ¡ticos audiovisuales

4.2. Learning outcomes

RA14 - RA4 - Capacidad para analizar los resultados

RA7 - RA6 ? RA25 ? Capacidad para comprender el funcionamiento básico de diferentes tipos de células solares, tanto actuales, como las que surjan en un futuro próximo.

RA15 - RA5 - Relacionar los principios básicos con los aspectos prácticos

RA4 - RA2 ? RA24 ? Conocimiento de los fundamentos físicos de las células solares

RA13 - RA3 - Conocer las herramientas de simulación más utilizadas para células y sistemas FV

RA11 - RA12 ? RA37 ? Comprender los principios físicos relevantes que afectan al funcionamiento de las células solares

RA12 - RA11 ? RA39 ? Capacidad para comprender los fundamentos físicos de las células solares actuales y de

nueva generación

RA16 - RA27 - Capacidad crítica para analizar los diferentes modelos en términos de principios básicos de la física

* 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

This course introduces the student to the simulation of solar cell devices and their interconnection into PV modules and presents different software tools frequently used in the field of photovoltaics. The main objective of the course is to provide training in the use of the software tools and to develop the student's capabilities of analysis, design and optimisation of PV devices.

The software utilised in the subject includes PC1D, SCAPS, and Microcap (SPICE). It is strongly recommended that students count with their own Windows-based (or compatible) personal computer.

The contents are grouped into thematic blocks, simultaneously revisiting theoretical concepts and introducing novel practical aspects, in the form of practice exercises that cover a wide range of topics, from fundamentals of charge carriers at microscopic level up to the evaluation of mismatch losses between cells at module level.

This subject follows the flipped clasroom methodology.

5.2. Syllabus

1. PC1D

   1.1. Si-based solar cell: emitter optimisation, sheet resistance, front-grid dimensioning, and figure of merit

   1.2. Comparison with the analytic model

2. SCAPS

   2.1. Thin-film, heterojunction-based solar cells

   2.2. Advanced simulation and optimisation

3. Microcap (SPICE)

   3.1. Equivalent electric circuit of a solar cell

   3.2. Multijunction solar cell and operation under concentrated light

   3.3. Interconnection, modules, mismatch and bypass diodes

   3.4. Interconnection optimization

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Introduction** Duration: 02:00 Lecture			
2	**Basics of PC1D** Duration: 02:00 Lecture			
3		**PC1D - Optimization of silicon-based solar cells** Duration: 02:15 Laboratory assignments		**Lab assignment** Individual work Continuous assessment Not Presential Duration: 03:00
4		**PC1D -Comparison with analytic model** Duration: 02:15 Laboratory assignments		**Lab assignment** Individual work Continuous assessment Not Presential Duration: 03:00
5	**Basics of SCAPS** Duration: 02:00 Lecture			
6		**SCAPS - Thin-film, heterojunction-based solar cells** Duration: 02:15 Laboratory assignments		**Lab assignment** Individual work Continuous assessment Not Presential Duration: 03:00
7		**SCAPS - Advanced simulation** Duration: 02:15 Laboratory assignments		**Lab assignment** Individual work Continuous assessment Not Presential Duration: 03:00
8	**Basics of Microcap and equivalent circuit modelling** Duration: 02:00 Lecture			
9		**Microcap - Equivalent circuit of a solar cell** Duration: 02:15 Laboratory assignments		**Lab assignment** Individual work Continuous assessment Not Presential Duration: 03:00
10		**Microcap - Multijunction solar cell and operation under concentrated light** Duration: 02:15 Laboratory assignments		**Lab assignment** Individual work Continuous assessment Not Presential Duration: 03:00

11		**Microcap - Cell interconnection, modules, mismatch and bypass diodes** Duration: 02:15 Laboratory assignments		**Lab assignment** Individual work Continuous assessment Not Presential Duration: 03:00
12		**Microcap - Interconnection optimization** Duration: 02:15 Laboratory assignments		**Lab assignment** Individual work Continuous assessment Not Presential Duration: 03:00
13	**Closing session** Duration: 02:00 Lecture			
14				
15				
16				
17				**Examen final** Problem-solving test Final examination Presential Duration: 03:00

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
3	Lab assignment	Individual work	No Presential	03:00	12.5%	/ 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8 CG9 CT3 CE1 CE2
4	Lab assignment	Individual work	No Presential	03:00	12.5%	/ 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8 CG9 CT3 CE1 CE2
6	Lab assignment	Individual work	No Presential	03:00	12.5%	/ 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8 CG9 CT3 CE1 CE2

7	Lab assignment	Individual work	No Presential	03:00	12.5%	/ 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8 CG9 CT3 CE1 CE2
9	Lab assignment	Individual work	No Presential	03:00	12.5%	/ 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8 CG9 CT3 CE1 CE2
10	Lab assignment	Individual work	No Presential	03:00	12.5%	/ 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8 CG9 CT3 CE1 CE2
11	Lab assignment	Individual work	No Presential	03:00	12.5%	/ 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8 CG9 CT3 CE1 CE2

12	Lab assignment	Individual work	No Presential	03:00	12.5%	/ 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8 CG9 CT3 CE1 CE2

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Examen final	Problem-solving test	Face-to-face	03:00	100%	5 / 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8 CG9 CT3 CE1 CE2

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Examen de convocatoria extraordinaria	Problem-solving test	Face-to-face	03:00	100%	5 / 10	CB6 CB7 CB8 CB9 CB10 CG3 CG5 CG8

						CG9 CT3 CE1 CE2

7.2. Assessment criteria

Progressive evaluation: Course marks will be calculated as the mean value of assignment marks obtained by the student, to be solved on an individual basis. A minimum of 5 points over 10 is necessary to pass the course.

Global evaluation by exam: if failed by progressive evaluation, the student can still pass the course. A minimum mark of 5 points over 10 is necessary to pass the course. The same will apply for the extraordinary examination.

Any evaluation activity described may additionally be complemented with a personal oral examination in order to validate that the student's assignments have not been completed with the aid of AI-systems.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
PV-CD-ROM	Web resource	Online PV resources
PV Lighthouse	Web resource	Online PV resources
Software user's manuals	Bibliography	Software-tool specific
Scientific articles and related biliography	Bibliography	Additional documentation
Slides and class material	Bibliography	

9. Other information

9.1. Other information about the subject

The goals and content of this course are aligned with the Sustainable Development Goals (SDGs), as the rest of the subjects in the Master Degree on PV Solar Energy. The promotion of PV solar energy has clear links with SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action) and SDG 9 (Industries, Innovation and Infrastructures)