



POLITÉCNICA

INTERNATIONAL  
CAMPUS OF  
EXCELLENCE

COORDINATION PROCESS OF  
LEARNING ACTIVITIES  
PR/CL/001



E.T.S. de Ingenieros de  
Telecomunicacion

# ANX-PR/CL/001-01

## LEARNING GUIDE

### SUBJECT

93001049 - Simulation Laboratory Of Cells And Systems

### DEGREE PROGRAMME

09AX - Master Universitario en Energia Solar Fotovoltaica

### ACADEMIC YEAR & SEMESTER

2020/21 - 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>            | 93001049 - Simulation Laboratory Of Cells And Systems           |
| <b>No of credits</b>                  | 4 ECTS  |
| <b>Type</b>                           | Optional  |
| <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>               | 09AX - Master Universitario en Energia Solar Fotovoltaica       |
| <b>Centre</b>                         | 09 - Escuela Tecnica Superior de Ingenieros de Telecomunicacion |
| <b>Academic year</b>                  | 2020-21   |

## 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>                                   |
|---|--------------------|----------------------|---|
| David Fuertes Marron<br>(Subject coordinator) | IES 201            | david.fuertes@upm.es | Tu - 17:00 - 18:00<br>with previous e-mail<br>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

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### 3.1. Recommended (passed) subjects

- Ingenieria De Los Sistemas Fotovoltaicos
- Fundamentos De Celulas Solares

### 3.2. Other recommended learning outcomes

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

## 4. Skills and learning outcomes \*

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### 4.1. Skills to be learned

CB06 - 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

CB07 - 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

CB08 - 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

CB09 - 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

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.

CE02 - Conocimiento, análisis y propuestas de nuevos conceptos, métodos o dispositivos para la conversión fotovoltaica

CE05 - Diseño, análisis, caracterización, planificación e instalación de componentes y sistemas fotovoltaicos de propósito general, autónomos o conectados a la red.

CE07 - Analizar, diseñar e implementar sistemas fotovoltaicos de complejidad media-alta

CG03 - Creatividad: Concebir, desarrollar y validar nuevos sistemas que puedan aumentar la calidad de vida de las personas; Realizar, en contextos académicos y profesionales, innovaciones o avances tecnológicos que puedan hacer avanzar el estado del arte

CG05 - Gestión de la información: buscar y gestionar recursos bibliográficos adecuados con eficiencia, aprender a continuar los estudios de manera ampliamente autónoma como base para la futura actividad de investigación e innovación

CG08 - Aplicar metodologías, procedimientos, herramientas y normas del estado del arte para la creación de nuevos componentes tecnológicos; Construir nuevas hipótesis y modelos, evaluarlos y aplicarlos a la resolución de problemas

CG09 - Comunicar juicios, y conocimientos a audiencias especializadas y no especializadas, de una manera razonada, clara y sin ambigüedades

CT03 - Uso de la lengua inglesa: comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa; redactar en inglés informes y artículos científico-técnicos usando herramientas informáticas; realizar exposiciones públicas en inglés de trabajos, resultados y conclusiones de investigación, por ejemplo, en las asignaturas del Máster o en congresos de carácter mayoritariamente internacional o en estancias en centros extranjeros, todo ello con la ayuda de medios informáticos audiovisuales

## 4.2. Learning outcomes

RA17 - RA4 - Capacidad para analizar los resultados

RA42 - RA3 - Conocer las herramientas de simulación más utilizadas para células y sistemas fotovoltaicos

RA13 - RA5 - Relacionar los principios básicos con los aspectos prácticos

\* 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

This subject introduces the student to the simulation of solar cell devices, modules and grid-connected systems and presents different software tools frequently used in the field of photovoltaics. The main objective of the subject 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 and systems.

The software utilised in the subject includes PC1D, SCAPS, Microcap (SPICE) and SISIFO.

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 energy production forecasting in large grid-connected systems.

This subject follows the flipped classroom methodology.

## 5.2. Syllabus

### 1. PC1D

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

### 2. SCAPS

- 2.1. Heterojunction-based solar cells
- 2.2. Advanced simulation and optimisation

### 3. Microcap (SPICE)

- 3.1. Equivalent electric circuit of a solar cell
- 3.2. Interconnection, modules, mismatch and bypass diodes
- 3.3. Interconnection optimization

### 4. SÍSIFO

- 4.1. Radiation, turbidity and temperature data
- 4.2. Analysis of daily and instantaneous operation conditions
- 4.3. Inclination & orientation angles and distance between lines in PV-generators
- 4.4. Grid-connected systems: sizing the inverter and final system design

## 6. Schedule

### 6.1. Subject schedule\*

| Week | Face-to-face classroom activities      | Face-to-face laboratory activities   | Distant / On-line | Assessment activities   |
|------|--|--|-------------------|---|
| 1    | <b>Introduction</b><br>Duration: 03:00 |  |                   |   |
| 2    |  | <b>PC1D - Silicon-based solar cell</b><br>Duration: 03:00                                      |                   | <b>Hoja de ejercicios</b><br>Continuous assessment<br>Not Presential<br>Duration: 03:00 |
| 3    |  | <b>SCAPS - Heterojunction-based solar cells</b><br>Duration: 03:00                             |                   | <b>Hoja de ejercicios</b><br>Continuous assessment<br>Not Presential<br>Duration: 03:00 |
| 4    |  | <b>SCAPS - Advanced simulation</b><br>Duration: 03:00  |                   | <b>Hoja de ejercicios</b><br>Continuous assessment<br>Not Presential<br>Duration: 03:00 |
| 5    |  | <b>Microcap - Equivalent circuit of a solar cell</b><br>Duration: 03:00                        |                   | <b>Hoja de ejercicios</b><br>Continuous assessment<br>Not Presential<br>Duration: 03:00 |
| 6    |  | <b>Microcap - Cell interconnection, modules, mismatch and bypass diodes</b><br>Duration: 03:00 |                   | <b>hoja de ejercicios</b><br>Continuous assessment<br>Not Presential<br>Duration: 03:00 |
| 7    |  | <b>Microcap - Interconnection optimization</b><br>Duration: 03:00                              |                   | <b>Hoja de ejercicios</b><br>Continuous assessment<br>Not Presential<br>Duration: 03:00 |
| 8    |  | <b>SISIFO - Radiation data, temperature and turbidity</b><br>Duration: 03:00                   |                   | <b>Hoja de ejercicios</b><br>Continuous assessment<br>Not Presential<br>Duration: 03:00 |
| 9    |  | <b>SISIFO - Analysis of daily and instantaneous operation conditions</b><br>Duration: 03:00    |                   | <b>Hoja de ejercicios</b><br>Continuous assessment<br>Not Presential<br>Duration: 03:00 |



|    |                                    |  |  |  |
|----|------------------------------------|--|--|--|
| 10 |                                    | SISIFO - Inclination and orientation angles, distance between generator lines<br>Duration: 03:00 |  | Hoja de ejercicios<br>Continuous assessment<br>Not Presential<br>Duration: 03:00 |
| 11 |                                    | SISIFO - Relative size of generator and inverter and final design<br>Duration: 03:00             |  | Hoja de ejercicios<br>Continuous assessment<br>Presential<br>Duration: 03:00     |
| 12 | Closing session<br>Duration: 03:00 |  |  |  |
| 13 |                                    |  |  |  |
| 14 |                                    |  |  |  |
| 15 |                                    |  |  |  |
| 16 |                                    |  |  |  |
| 17 |                                    |  |  | Examen final<br>Final examination<br>Presential<br>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. Continuous assessment

| Week | Description        | Modality | Type          | Duration | Weight | Minimum grade | Evaluated skills   |
|------|--------------------|----------|---------------|----------|--------|---------------|--|
| 2    | Hoja de ejercicios |          | No Presential | 03:00    | 10%    | / 10          | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |
| 3    | Hoja de ejercicios |          | No Presential | 03:00    | 10%    | / 10          | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |
| 4    | Hoja de ejercicios |          | No Presential | 03:00    | 10%    | / 10          | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |

|   |                    |  |               |       |     |      |  |
|---|--------------------|--|---------------|-------|-----|------|--|
| 5 | Hoja de ejercicios |  | No Presential | 03:00 | 10% | / 10 | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |
| 6 | hoja de ejercicios |  | No Presential | 03:00 | 10% | / 10 | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |
| 7 | Hoja de ejercicios |  | No Presential | 03:00 | 10% | / 10 | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |
| 8 | Hoja de ejercicios |  | No Presential | 03:00 | 10% | / 10 | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |

|    |                    |  |               |       |     |      |  |
|----|--------------------|--|---------------|-------|-----|------|--|
| 9  | Hoja de ejercicios |  | No Presential | 03:00 | 10% | / 10 | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |
| 10 | Hoja de ejercicios |  | No Presential | 03:00 | 10% | / 10 | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |
| 11 | Hoja de ejercicios |  | Face-to-face  | 03:00 | 10% | / 10 | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03<br>CE05<br>CB08<br>CB07 |

### 7.1.2. Final examination

| Week | Description  | Modality | Type         | Duration | Weight | Minimum grade | Evaluated skills   |
|------|--------------|----------|--------------|----------|--------|---------------|--|
| 17   | Examen final |          | Face-to-face | 03:00    | 100%   | 5 / 10        | CG08<br>CB09<br>CG09<br>CE02<br>CE07<br>CB06<br>CG05<br>CB10<br>CG03<br>CT03 |



## 7.2. Assessment criteria

Final marks will be calculated as the mean value of califications obtained in the 10 exercises proposed in the practical sessions. A minimum of 5 points over 10 is necessary to pass the subject.

Evaluation by final exam (upon request) will consist of the mark obtained in it. The same will apply for the extraordinary examination.

## 8. Teaching resources

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### 8.1. Teaching resources for the subject

| Name                      | Type         | Notes                    |
|---------------------------|--------------|--------------------------|
| PV-CD-ROM                 | Web resource |                          |
| Manuales de software      | Bibliography | Software-tool specific   |
| Artículos y documentación | Bibliography | Additional documentation |