ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93001036 - Solar Cell Characterization Laboratory

DEGREE PROGRAMME

09AX - Master Universitario en Energia Solar Fotovoltaica

ACADEMIC YEAR & SEMESTER

2020/21 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	93001036 - Solar Cell Characterization Laboratory
No of credits	4 ECTS
Type	Compulsory
Academic year ot the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	09AX - Master Universitario en Energia Solar Fotovoltaica
Centre	09 - Escuela Tecnica Superior de Ingenieros de Telecomunicacion
Academic year	2020-21

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Ignacio Rey-Stolle Prado (Subject coordinator)	IES-107	ignacio.reystolle@upm.es	Tu - 10:00 - 12:00

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

2.2. Research assistants

Name and surname	Email	Faculty member in charge
Garcia Vara, Ivan	ivan.garciav@upm.es	Rey-Stolle Prado, Ignacio

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

3.2. Other recommended learning outcomes

- Solar cell basics

- Fundamentals of electrical measurements

- Basic electrical instrumentation

- Measurement theory and uncertainty analysis

4. Skills and learning outcomes *

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

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.

CE03 - Realización, desarrollo e innovación de procesos tecnológicos para la fabricación de dispositivos fotovoltaicos.

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

CG04 - Organización y planificación: Organizar, planificar y gestionar proyectos complejos y multidisciplinares que involucren varios de los aspectos tratados en el Máster

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

CG06 - Gestión económica y administrativa: Analizar críticamente y diseñar sistemas y soluciones complejos, aplicar tecnologías para gestionar y afrontar la complejidad con un enfoque sistémico; emitir juicios sobre las implicaciones económicas, sociales, éticas y medioambientales ligadas a la aplicación de sus conocimientos (respetando los principios de igualdad y universalidad de acceso); Analizar, seleccionar, diseñar e integrar tecnologías con un adecuado criterio técnico-económico

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

CT04 - Liderazgo de equipos: realizar trabajos en equipo (como los de algunas de las actividades de evaluación de las asignaturas), integrarse en un grupo de investigación participando activamente en sus reuniones, colaborando con iniciativa propia en trabajos o proyectos de I+D+i; interaccionar con efectividad con los miembros del equipo de trabajo multidisciplinar

4.2. Learning outcomes

RA4 - RA32 - Capacidad para analizar y medir las curvas i-v de células solares

RA7 - RA33 - Formación en los aspectos prácticos de la caracterización de células solares

* 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

The general cognitive goal for this course is **to master the methods and instrumentation needed for the basic characterization of solar cell devices.**

In particular, this general goal will be achieved by reaching the following set of specific goals:

- To master the basic techniques for solar cell characterization
- To understand the main factors influencing solar cell electrical characteristics
- To know the international standards related to measurements on solar cells
- To operate electrical instrumentation needed for solar cell characterization
- To know the operating principles and characteristics of solar simulators
- To identify the quality parameters of an experimental measurement
- To know how to accurately present experimental data

5.2. Syllabus

1. Preliminary issues: Lab. safety and etiquette

2. Basic Instrumentation and Methods to Measure a Solar Cell I-V Curve

3. Solar Simulators

4. I-V Curve Measurement (1). The reference cell method

5. I-V Curve Measurement (2). Influence of key parameters

6. I-V Curve Measurement (3). Measurements following the standard

7. Upscaling from solar cells to PV modules, arrays and plants.

6. Schedule

6.1. Subject schedule*

Week	Face-to-face classroom activities	Face-to-face laboratory activities	Distant / On-line	Assessment activities
1	**Introduction to the Course** Duration: 02:00 **Theory class for Lab session 1** Duration: 02:00			
2				
3	**Theory class for Lab session 2** Duration: 02:00	**Lab Session 2: Basic Instrumentation and Methods** Duration: 02:30		**Report for lab session 1** Continuous assessment Not Presential Duration: 06:00
4	**Theory class for Lab session 3** Duration: 02:00	**Lab session 3: Solar Simulators** Duration: 02:30		**Report for lab session 2** Continuous assessment Not Presential Duration: 06:00
5	**Theory class for Lab session 4** Duration: 02:00	**Lab session 4: I-V Curve Measurement (1). The reference cell method** Duration: 02:30		**Report for lab session 3** Continuous assessment Not Presential Duration: 06:00
6	**Theory class for Lab session 5** Duration: 02:00	**Lab session 5: I-V Curve Measurement (2). Influence of key parameters** Duration: 02:30		**Report for lab session 4** Continuous assessment Not Presential Duration: 06:00
7	**Theory class for Lab session 6** Duration: 02:00	**Lab session 6: I-V Curve Measurement (3). Measurements following the standard** Duration: 02:30		**Report for lab session 5** Continuous assessment Not Presential Duration: 06:00
8	**Theory class for Lab session 7** Duration: 03:00			**Report for lab session 6** Continuous assessment Not Presential Duration: 06:00
9				**Report for lab session 7** Continuous assessment Not Presential Duration: 06:00

10				
11				**Final theory exam** Continuous assessment Presential Duration: 04:00
12				**Final practical exam in the lab** Continuous assessment Presential Duration: 04:00
13				
14				
15				
16				
17				**Final combined theory/practical exam** Final examination Presential Duration: 04:00

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
3	Report for lab session 1		No Presential	06:00	7%	5 / 10	CE03 CG05 CB08 CT03 CG06 CG08 CB06 CT04 CB10 CG03 CG09 CB07 CG04
4	Report for lab session 2		No Presential	06:00	7%	5 / 10	CB08 CT03 CE03 CG05 CG06 CG08 CB06 CT04 CB10 CG03 CG09 CB07 CG04
5	Report for lab session 3		No Presential	06:00	7%	5 / 10	CB08 CT03 CE03 CG05 CG06 CG08 CB06 CT04 CB10 CG03 CG09 CB07 CG04

6	Report for lab session 4		No Presential	06:00	7%	5 / 10	CB08 CT03 CE03 CG05 CG06 CG08 CB06 CT04 CB10 CG03 CG09 CB07 CG04
7	Report for lab session 5		No Presential	06:00	7%	5 / 10	CB08 CT03 CE03 CG05 CG06 CG08 CB06 CT04 CB10 CG03 CG09 CB07 CG04
8	Report for lab session 6		No Presential	06:00	7%	5 / 10	CB08 CT03 CE03 CG05 CG06 CG08 CB06 CT04 CB10 CG03 CG09 CB07 CG04
9	Report for lab session 7		No Presential	06:00	8%	5 / 10	CB08 CT03 CE03 CG05 CG06 CG08 CB06 CT04 CB10 CG03 CG09 CB07 CG04

11	Final theory exam		Face-to-face	04:00	25%	5 / 10	CB08 CT03 CB06 CB07
12	Final practical exam in the lab		Face-to-face	04:00	25%	5 / 10	CB08 CT03 CE03 CG05 CG08 CB06 CB10 CG09 CB07

7.1.2. Final examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Final combined theory/practical exam		Face-to-face	04:00	100%	6 / 10	CB08 CT03 CE03 CG05 CG06 CG08 CB06 CT04 CB10 CG03 CG09 CB07 CG04

7.1.3. Referred (re-sit) examination

No se ha definido la evaluación extraordinaria.

7.2. Assessment criteria

CONTINUOUS ASSESSMENT

Lab Session Reports

The complete 7 session reports will account for 50% of the grade. Each of the Lab teams should deliver a single report per lab session (i.e. these reports will be teamwork). The assessment criteria for each of these reports will be as follows:

- Structure and scientific format (30%). How is the text structured and the information displayed; quality of graphs and figures; treatment of uncertainties; delay in delivering the report, etc.
- Empirical data quality (30%). Completeness of empirical data set (did you measure everything?); quality of measurements (did you use appropriate instruments and ranges?); observation errors.
- Discussions (40%). Clarity, conciseness, and accuracy of the discussions included to interpret the results or answer the questions in the report.

Final Practical Exam

25% of the final score will be associated with an individual practical exam to be carried out in the lab. Such a practical exam will be similar to a lab session but will be conducted individually. In this exam, you will face a lab situation similar to those realized during the lab sessions. The criteria that will be followed to assess this test are:

- How standard test conditions are set (20%)
- How the monitor solar cell is set in place (10%)
- How the preliminary measurement with a multimeter is done (20%)
- How the connections and 4-wire method are implemented (20%)
- How computer programs are mastered (10%)
- Answers to questions during the course of the exam (20%)

Final Theory Test

25% of the final score will be the result of a written test. The test will consist of 20 brief multiple-choice questions about topics covered in the course. No ancillary material other than a calculator can be used in the exam.

The test will be assessed as follows: the score will range from 0 to 10 points; every question correctly answered will add 1/2 to the final count; for every question failed 1/6 will be subtracted to the final count; questions with no answer (i.e. when no option is marked) neither add nor subtract.

ASSESSMENT WITH FINAL TEST ONLY

To pass this course it is a must to carry out all lab sessions. Therefore, this assessment process with "final test only" will be only for those failing to pass the course with the continuous assessment.

The final score will be the result of a combined theory a practical test following the same criteria presented for the "continuous assessment".

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Course Web page in Moodle	Web resource	The course web page at UPM's Moodle server contains all material needed to follow the course. This includes: * Presentations for all lab sessions * Lab session guides * Additional material (readings, videos, Matlab programs, Excel sheets, data ...)
Solar cell characterization lab	Equipment	The Solar Cell Characterization Facility at the Solar Energy Institute of the Technical University of Madrid will be the lab used for this course.

9. Other information

9.1. Other information about the subject

This course is related to SUSTAINABLE DEVELOPMENT GOAL 7, "Ensure access to affordable, reliable, sustainable and modern energy for all". In particular, to its specific target "7.1 By 2030, increase substantially the share of renewable energy in the global energy mix". This course aims at mastering the tools and methods to measure the basic photovoltaic devices and thus constitutes fundamental knowledge for the impulse and penetration of Photovoltaic Solar Energy.