COURSE DATA

Data Subject	
Code	36402
Name	Renewable energies and solar radiation
Cycle	Grade
ECTS Credits	7.5
Academic year	2021 - 2022

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	4	First term

Subject-matter

Degree	Subject-matter	Character
1105 - Degree in Physics	16 - Complements of Physics	Optional

Coordination

Name	Department
GOMEZ AMO, JOSE LUIS	345 - Earth Physics and Thermodynamics
SORIA BARRES, GUILLEM PAU	345 - Earth Physics and Thermodynamics
UTRILLAS ESTEBAN, MARIA DEL PILAR	345 - Earth Physics and Thermodynamics

SUMMARY

The course «Renewable Energies and Solar Radiation» is taught, as an optional matter, in the first semester of the fourth year in the Physics degree.

This course must provide the students the physical basis necessary to understand issues related to the environmental physics and renewable energy, as well as the appropriate tools to solve them quantitatively. Climate change and the energy transition constitute one of the most important and urgent challenges currently facing globally. Therefore, it is urgently necessary to find mitigation strategies for the former by improving knowledge of the climate system. All the most promising solutions from the technological point of view and the most competitive from the economic point of view go through the increase in renewable energies use as an alternative to classic energy sources, which are limited and polluting.

The subject does not focus exclusively on the world of scientific, technological or industrial knowledge, but also has a strong content of a social and human nature. For this reason, the development of the program is not based exclusively on the study of academic problems that allow establishing the basic concepts and fundamental work techniques, but also introduces students to the pressing problems that affect our time and Scientific-technical applications that can help us solve these problems. It is about preparing students adequately for their occupational work to be developed later and that is related to the knowledge and improvement of the environment that surrounds us and the energy management that can lead to achieving these ends.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

No prerequisites are required

COMPETENCES (RD 1393/2007) // LEARNING OUTCOMES (RD 822/2021)

1105 - Degree in Physics

- Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.
- To know how to apply the knowledge acquired to professional activity, to know how to solve problems and develop and defend arguments, relying on this knowledge.
- Ability to collect and interpret relevant data in order to make judgements.
- Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .
- Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.
- Physics general culture: Be familiar with the most important areas of physics and with those approaches which span many areas in physics, or connections of physics with other sciences.
- Basic & applied Research: acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.
- Foreign Language skills: Have improved command of English (or other foreign languages of interest) through: use of the basic literature, written and oral communication (scientific and technical English), participation in courses, study abroad via exchange programmes, and recognition of credits at foreign universities or research centres.

- Literature Search: be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development.
- Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.
- Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.
- Students must have acquired knowledge and understanding in a specific field of study, on the basis of general secondary education and at a level that includes mainly knowledge drawn from advanced textbooks, but also some cutting-edge knowledge in their field of study.
- Students must be able to apply their knowledge to their work or vocation in a professional manner and have acquired the competences required for the preparation and defence of arguments and for problem solving in their field of study.
- Students must have the ability to gather and interpret relevant data (usually in their field of study) to make judgements that take relevant social, scientific or ethical issues into consideration.
- Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.
- Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

LEARNING OUTCOMES (RD 1393/2007) // NO CONTENT (RD 822/2021)

1. Identify and delimit the Earth-Sun system in a real problem, fixing the magnitudes that describe its space / time variation, as well as the parameters that determine its ties.
2. Know the different radiometric magnitudes and their scope of application (radiation, irradiance, irradiation, etc.).
3. Describe the characteristics of solar and thermal radiation in their interaction with the atmosphere, analyzing its main attenuation mechanisms through its reflection, absorption, dispersion and extinction processes.
4. Approach of the radiative transfer equation and evaluate the different approaches and implications in the terrestrial radiative balance, according to the case study.
5. Characterize the components of solar radiation and how to determine them on planes of different orientation and inclination.
6. Identify the fundamental properties associated with the different forms of renewable energy, as well as detail the physical phenomena involved and their technical characteristics.
7. Evaluate and interpret the different parameters used in the analysis of energy performance associated with technological applications derived from the production and consumption of renewable energy sources.
8. Dominate the necessary mathematical tools in an elementary context of alternative energy management, according to the type in question.
9. Dominate the computing tools of calculation and simulation used in solving mathematical problems derived from energy analysis to evaluate the production and performance associated with different

forms of energy.

10. Other skills transversal to the rest of the degree subjects are: the management of the physical unit systems, the approach skills, the ability to interpret graphic information, the use of elemental simulation techniques and, in general, the critical analysis of everything. kind of situations.

DESCRIPTION OF CONTENTS

1. Radiometric quantities

Solid angle.
Basic radiometric quantities.
Spectral radiometric magnitudes.
Relationship between radiance and flux density.
Radiant energy density.

2. Interaction of radiation with matter

Interaction mechanisms
Reflection
Planetary albedo
Absorption
Dispersion
Extinction
Relationships between reflectance, absorbance and transmittance

3. Sources of radiation. Issue

Radiation sources
Black body radiation
Emissivity
Selective surfaces
The Sun and Earth as sources of radiation

4. Absorption

Origin of the spectral lines
Profile of a spectral line
Widening of a spectral line
Line intensity
Total absorption in one line. Equivalent width
Band models. Definitions
Regular or Elsasser model
Random models

Average intensity and half width

5. Dispersion by molecules and particles

Attenuation of radiation by scattering.
Rayleigh theory of molecular dispersion
Rayleigh scattering parameters
Bases of Mie's theory for particle dispersion.
Mie dispersion coefficients

6. The radiative transfer equation

Radiance balance in a volume element
Source function
Beer's law and Schwarzild's equation
Plane-parallel atmospheres
Resolution of the ETR in a non-dispersive atmosphere. Problem Statement
Radiation expressions
Isothermal atmosphere. Cooling approach into space
ETR in a dispersive atmosphere
Parameterization of the phase function
ETR resolution in a dispersive atmosphere

7. Absorption and dispersion by gaseous components in the Earth's atmosphere

UV absorption
Absorption in the visible and near IR
Absorption in thermal IR and microwave
Optical mass
Transmittances
Molecular dispersion. Parametric approximations
Empirical expressions for particle dispersion. Turbidity coefficients

8. Atmospheric aerosols

Introduction: the role of aerosols in the atmosphere
Physical and radiative properties
Determination of the optical thickness from radiation measurements
Determination of size distribution. Models
Aerosol Climate Models
Aerosols and human health

9. Clouds. Radiation balance

Clouds and the equilibrium temperature of the earth-atmosphere system
Formation and growth of particles in a cloud
Microphysical properties of clouds. Size distribution
Radiative transfer in a cloud atmosphere
Parameterization of the radiative properties of clouds
Radiation Balance Overview
Radiation flux calculation
Atmospheric ceiling radiation balance (TOA)
Radiation balance on the Earth's surface

10. Radiation at the limit of the Earth's atmosphere

Relative distance Sun-Earth
Solar declination
Geographical coordinates
Equation of time
Solar coordinates
Radiation depending on the angle of incidence
Irradiance on a horizontal surface on the roof of the atmosphere
Irradiation on a horizontal surface on the roof of the atmosphere
Irradiation on an arbitrary surface on the roof of the atmosphere

11. Calculation of solar radiation at ground level: Parametric approximation

Justification
Components of solar radiation
Direct irradiance
Dispersion. Approximation of the two flows
Diffuse irradiance. Components
Global irradiance at ground level

12. Measurement of radiation and atmospheric components

Radiation measurements: general
Measurement of broadband solar radiation: direct, diffuse and global components
Measurement in different bands: ultraviolet and infrared
Albedo measurement
Spectral measurements
Measurement of the physical and radiative properties of aerosols
Renewable energy

13. Energy and human development

Concept of energy and its forms
Last. Cheap and abundant energy
The present. Social awareness
The future. Sustainable development
Alternative energies and renewable energies
Pollutant effects of energy

14. Wind energy

Wind energy and its historical use
Origin, characteristics and determination of the wind resource
Estimation of energy production
Wind turbines
Wind plants and applications
Advantages, disadvantages and environmental impact of wind energy

15. Photovoltaic energy

The photovoltaic effect
The solar cell and its characteristic curve
Performance and operation indicators
Association of cells in series and in parallel
From the module to the photovoltaic plant. Applications
Advantages, disadvantages and environmental impact of photovoltaic energy

16. Thermal solar energy

Some historical notes
Optical properties of materials
Thermal properties of materials and heat transfer mechanisms

17. Low temperature thermal solar energy

The flat solar collector and its energy balance equation
Performance evaluation of the flat solar collector
Types of low temperature solar collectors
Low temperature applications

18. Medium and high temperature solar thermal energy

Solar concentration, types of concentrators
Thermoelectric solar power generation
Some applications of solar thermal energy

19. Biomass energy

Biomass concept
Organic waste
Biomass to energy conversion
Energy crops
Biofuels
Advantages and disadvantages of biomass energy

20. Other alternative energies

Hydraulic energy
Geothermal energy
Energy from the sea
 Tidal energy
 Wave energy
 Energy of marine currents
 Energy of marine gradients

21. Laboratory

P1. Solar radiation.
Earth-Sun astronomical relations. Radiometer calibration. Variation of irradiance with the zenith angle. Know and manage devices for measuring solar radiation. Calibration of the measuring devices. Analysis of integrated solar radiation data. Radiative transfer models to study the reflectivity and transmissivity of different surfaces. Study and calculate some properties such as transmissivity, reflectivity, etc., of different surfaces through the study of radiative transfer models.

P2. Wind power.
Study of a wind turbine. Analyze the wind resource: speed, direction and frequency distribution of the wind. Compass Rose. Obtain the real available power, maximum profitable and profitable curves of a wind turbine. Study the behavior of a wind turbine as a function of the speed distribution. Obtain the angular distribution of power generated by the wind turbine.

P3. Thermal solar energy.
Study of a flat solar collector. Study the characteristics and behavior of a flat solar panel. Determine your performance curve. Obtain the values of the heat extraction factor and its global loss coefficient. Analyze its operation over time and that of temperature variations.

P4. Photovoltaic Solar Energy.
Study of photovoltaic modules and their associations Analyze the structure and behavior of a photovoltaic module. Obtain its characteristic curve and find the point of maximum power. Study the dependence of the module on the received irradiance. Performance analysis. Obtain the characteristic curves of modules connected in series and parallel and their maximum power point. Study the dependence of the modules on the received irradiance. Association performance.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	45,00	100
Laboratory practices	30,00	100
Development of group work	20,00	0
Development of individual work	10,00	0
Study and independent work	64,00	0
Preparation of practical classes and problem	18,50	0
TOTAL	**187,50**	

TEACHING METHODOLOGY

The course has two parts with a well differentiated methodology: A) Lectures and B) Laboratory. The development of the classes is as follows:

Lectures

Theoretical and problem solving credits are structured in three class hours per week, with a variable proportion of theory and problems according to the subject. The working methodology can be classified into the following sections:

Theory: The teacher teaches the theoretical content, generally following the model of the master lesson and based on different materials (presentation of slides, notes, figures and blackboard) that will be previously provided to the students.

Problem solving: This part has a double aspect: it contemplates individual study and the participation of students in class. Students have a collection of problems for each theory group, which can bring together several lessons, some of which will be solved in class (both by the students and the teacher). The teacher may leave some problems in the newsletters, or propose new ones, to be solved by the students outside the classroom.

Laboratory

The course is structured in eight laboratory sessions (one session each week) of 3 hours and 45 minutes each. These are taught in small subgroups, with a teacher assigned to each subgroup. In the sessions the students grouped in pairs carry out the practices. Attendance at these sessions is compulsory and a necessary condition to pass the course.

The student must go to the laboratory having carefully read the script of the practice that they will have to do in each session (previously known). At the beginning of the session, the teacher will supervise the understanding of this script and will guide the students on those conceptual or technical aspects necessary for the students to start correctly the acquisition of data.

For each practice, the couple must present a memory where the experimental data and their treatment (errors, graphs, adjustments) are collected, as well as the conclusions reached. Emphasis will be placed on the use of computer programs for data processing (spreadsheet), which can be done during the practical sessions with the computers available in the laboratory itself.

EVALUATION

The assessment of the course is done taking into account, proportionally, the parts of: A) Lectures and B) Laboratory.

A. LECTURES: 70%

The evaluation of this part of the subject will be based on a continuous evaluation in which the attendance and participation of the student in class, and the correction of the problems proposed for their resolution at home will be taken into account. An attendance greater than 80% and the grade corresponding to the correction of the proposed problems may lead to the PASSING of the course, with a maximum grade of 6.5.

As an alternative, every student will be able to take a written exam that may consist of different questions of theory and problems, theory and problems.

B. LABORATORY: 30%

Laboratory work is continuously evaluated based on the writing reports made by the students for each of the experiments planned during the course.

The final grade will be obtained as the weighted average of sections A and B, provided that a minimum of 4/10 is obtained in section A and 5/10 in section B. The total grade required to pass the course will be 5/10 points.

REFERENCES

Basic

- Iqbal, M.: Introduction to solar radiation Academic Press, 1983
- Lenoble, J.: Atmospheric radiative transfer. A. Deepak Pub., 1993
- Villarrubia, M.: Ingeniería de la energía eólica. Marcombo, 2012

- Castañer, L.: Energía solar fotovoltaica. Ediciones UPC, 1992
- Duffie, J. y Beckman, W.: Procesos térmicos en energía solar. Grupo Cero, 1979
- González, J.: Energías Renovables. Reverté. Barcelona. 2009
- Bohren and Clothiaux, Fundamentals of atmospheric radiation, Wiley, 2006

Additional

- Liou, K.N.: An introduction to atmospheric radiation, Elsevier, 2002
- Julian Chen, C.: Physics of solar energy, John Wiley & Sons, 2011
- Ortega. M.: Energías Renovables. Paraninfo. Madrid. 2000
- Brower. M. C: Wind resource assesment. A practical guide to developing a wind project, John Wiley & Sons, 2012

ADDENDUM COVID-19

This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council

TEACHING METHODOLOGY:

In case that health situation requires blended teaching, the teaching model approved by the Academic Degree Committee on July 23, 2020 will be adopted.

— Compulsory subjects: 50% student attendance in the classroom, while the rest of students attend the class in streaming broadcast. Two groups will be set with alternate days attendance to the classroom in order to guarantee 50% of teaching hours attendance for all students. Laboratory sessions will have a 100% attendance.

— Optional subjects: 100% attendance in all activities.

If a total reduction in attendance is necessary, classes will be broadcast by synchronous videoconference at their regular schedule, along the period determined by the Health Authority.