Thermal Subsystem

Academic Year: (2022 / 2023) **Review date: 25-04-2022**

Department assigned to the subject: Department of Thermal and Fluids Engineering

Coordinating teacher: ACOSTA IBORRA, ANTONIO

Type: Compulsory ECTS Credits : 2.0

Year : 1 Semester : 2

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Space Environment.
Complements to Aerospace Engineering (if the student does not have previous knowledge on basic thermal engineering, including heat transfer).

OBJECTIVES

1) Competences and skills that will be acquired in the subject.

a) Basic competences:

CB6 To possess and understand knowledge that provides a basis or opportunity to be original in the development and / or application of ideas, often in a research context
CB7 Students must know how to apply the knowledge acquired and their ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study
CB8 Students must be able to integrate knowledge and face the complexity of making judgments based on information that, being incomplete or limited, includes reflections on social and ethical responsibilities linked to the application of their knowledge and judgments
CB9 Students must know how to communicate their conclusions and the knowledge and ultimate reasons that sustain them to specialized and non-specialized audiences in a clear and unambiguous way
CB10 Students must have the learning skills allowing them to continue studying in a way that will be largely self-directed or autonomous.

b) General competences:

CG1 Capacity for the formulation, critical verification and defense of hypotheses, as well as the design of experimental tests for verification.
CG2 Ability to make value judgments and prioritize in making conflicting decisions using systemic thinking.
CG4 Ability to work in multidisciplinary teams in a cooperative way to complete work tasks
CG5 Ability to handle the English, technical and colloquial language.

c) Specific competences:

CE3 Ability to develop a complete system that meets the design specifications and the expectations of the interested parties. This includes the production of products; acquire, reuse or code products; integrate products in top-level assemblies; verify products against design specifications; validate the products against the expectations of the interested parties; and the transition of products to the next level of the system.
CE8 Ability to understand and apply the knowledge, methods and tools of space engineering to the analysis and design of the thermal subsystem of space vehicles.

2) Learning results.

a) General and specific learning outcomes:

After studying this subject, students will have knowledge about the vehicle, the environment and the different physical models needed to design a space platform. Specifically, the learning outcomes of the subject are those that appear below:

b) Transversal learning outcomes

The transversal learning outcomes (and evaluable in one or more subjects of the Spacecraft and Dynamics knowledge field, which contains the present subject) are related to the following sections of the CDIO curriculum:

- Section 2.1, analytical reasoning, and problem-oriented (for example, modeling or analysis with uncertainty).
- Section 2.2, experimentation, research and discovery of knowledge (for example, formulation of hypothesis or experimental inquiry).
- Section 2.4, personal skills and attitudes (for example, initiative and willingness to take risks or creative thinking).

DESCRIPTION OF CONTENTS: PROGRAMME

1. Introduction:
1.1. Thermal Control in space systems.
1.2. Classification of thermal control subsystems.

2. Spacecraft thermal Loads:
2.1. Spacecraft thermal environment.
2.2. Heat sources.
2.3. Thermal balance.
2.4. Practical examples and problems.

3. Thermal modelling:
3.1. Heat transfer modes in space systems.
3.2. Modelling of heat conduction exchange.
3.3. Modelling of heat convection exchange.
3.4. Modelling of radiative heat exchange.
3.5. Combined heat exchange.
3.6. Thermal analysis codes.
3.7. Practical examples and problems.

4. Thermal Subsystem Design:
4.1. Thermal requirements and constraints.
4.1. Passive thermal control.
Surface finishes, insulation systems, radiators, conduction paths, heat pipes and two-phase systems, phase change materials and ablative systems.
4.2. Active thermal control.
Heaters, louvers and shutters, refrigeration cycles, thermoelectric coolers, VCPHs and diodes, pumped liquid and two-phase loops, cryogenic systems and other thermal control systems.
4.3. Case study examples.

5. Thermal Subsystem Testing:
5.1. Thermal verification of models and hardware.
5.2. Thermal balance and thermal vacuum tests.
5.3. Case study examples.

6. Thermal control normative:
6.1. Aim and scope of thermal control normative.
6.2. The ECSS standards.

LEARNING ACTIVITIES AND METHODOLOGY

1) Learning activities followed in the course:

Theoretical class: lectures about each topic of the course.
Practical classes: solution of excercises and case study examples.
Practices in computer classroom: simulation laboratory.
Evaluacion activities: final exam, laboratory reports and assignments.

These learning activities imply group work and individual student work.

2) Teaching methodologies that are used in the subject:

Lectures delivered by the course instructor with support of computer and audiovisual media, in which the main concepts of the subject are developed and a bibliography is provided to complement the students' learning.

Solution, either individually or in group, of problems, case study, etcetera, raised by the instructor.

Preparation, either individually or in group, of projects and reports.

3) Tutoring sessions and communication with the students:

Students can request a tutoring session with the instructor within the office hours announced on the web page of the course (Aula Global, aulaglobal.uc3m.es). Communication with the students (notices, materials of the course, etcetera) will be mainly done through Aula Global.

ASSESSMENT SYSTEM

- The overall mark of the course in the first (ordinary) period of evaluation is obtained from the weighted mark of the following activities:

Final ordinary exam (50%)
Laboratory and assignments (projects and/or solution of exercises) (50%)

- The overall mark of the course in the second (retake) period of evaluation is obtained from the maximum of the following marks:

Mark1: weighted mark of the following activities:
Final retake exam (50%)
Laboratory and assignments (projects and/or solution of exercises) (50%)

Mark2: only the final retake exam mark without including other marks
Final retake exam (100%)

Overall mark of the course in the second (retake) period of evaluation = max (Mark1, Mark2)

- To pass the course, the following two requirements need to be met:

1) The mark of the final exam should be equal to or greater than 3.0 over 10.
2) The overall mark of the course should be equal to or greater than 5.0 over 10.

% end-of-term-examination:	50
% of continuous assessment (assigments, laboratory, practicals…):	50

BASIC BIBLIOGRAPHY

- European Cooperation for Space Standarization ECSS-E-ST-31C, Thermal Control, ESA, 2008
- F.P. Incropera, D.P. DeWitt, T.L. Bergman, A.S. Lavine Introduction to heat transfer (5th Edition), Wiley, 2006
- M.J. Moran, H.N. Shapiro Principles of Engineering Thermodynamics (7th Edition), John Wiley & Sons, 2012
- P. W. Fortescue, G. Swinerd, J. Stark Spacecraft Systems Engineering (4th Edition), Wiley, 2011

ADDITIONAL BIBLIOGRAPHY

- D.G. Gilmore (Editor) Spacecraft Thermal Control Handbook. Volume I: Fundamental Technologies (2nd Edition), AIAA, 2002
- J. Meseguer, I. Pérez-Grande, A. Sanz-Andrés Spacecraft thermal control, Woodhead Publishing, 2012
- M. Donabedian (Editor) Spacecraft Thermal Control Handbook. Volume II: Cryogenics, AIAA, 2003
- W.J. Larson, A.V. Wertz Space Mission Analysis and Design (3rd Edition), Kluwer Academic Publishers, 1999