Academic Year 2026/2027

Course Guide:

THERMAL ENGINEERING

FACULTY OF CHEMICAL SCIENCES

1. IDENTIFICATION

Degree Program	Bachelor's Degree in Chemical Engineering.	Course Code	801546
Course Name	Thermal Engineering	ECTS	9
Subject Area	Thermodynamics and Thermal Engineering		
Module	Industrial Engineering		
Course Type	Compulsory	Year	Third Year
		Semester	First
Department	Chemical Engineering and Materials		

Lecturers in Charge

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2. OBJECTIVES

General Objective

The objective of this course is to understand the basic mechanisms of heat transfer and the fundamental equations applied in each case. To raise awareness of the importance of insulation and heat recovery, as well as to model problems related to heat transfer and learn how to solve them.

Specific Objectives

- Be able to list situations in which heat transfer occurs.
- Explain the meaning of terms such as, heat, conduction, convection, radiation, individual and overall heat transfer coefficient, counter-current and parallel flow, temperature profile, thermal resistance.
- Know the operating principle and the range of application of temperature measuring instruments and the common heating and cooling agents.
- Be able to apply Fourier's law to planar, cylindrical and spherical geometries.
- Calculate heat flux by conduction in a solid or in a fluid at rest.
- Determine the temperature profile across the thickness of a solid or of a fluid at rest where convection does not occur.
- Analyse conduction in the operation of extended surfaces or fins.
- Calculate one-dimensional transient conductive heat flow in a flat plate, cylinder and sphere.
- Apply the negligible internal resistance method.
- Apply other alternative methods such as spatial effects.
- Understand the fundamentals of energy transport by convection and the definition of the individual heat transfer coefficient.
- Establish the most common dimensionless numbers used to group the variables involved in convective heat transfer in internal flow.
- List and explain the main effects to consider when calculating coefficients from experimental correlations.
- Present the main experimental correlations for internal flow.
- Establish and estimate heat transfer coefficients in systems of simple geometry and of industrial interest for forced convection.
- Identify the mechanism of natural convection for a given application.
- Present the main experimental correlations for external flow.
- Evaluate the heat flux transmitted in a boiling liquid.
- Evaluate the critical heat flux in nucleate boiling and calculate the individual heat transfer coefficient in a boiling liquid.
- Calculate individual heat transfer coefficients for condensing vapour depending on solid geometry and the type of condensation.
- Explain terms such as, nucleate boiling, film boiling, dropwise condensation, annular flow, etc.
- Calculate transport resistance (overall heat transfer coefficient as a function of fluid resistances and geometry).
- Describe the thermal design method for heat exchangers (DTML): calculation of required area. Apply the method to concentric-tube exchangers, shell-and-tube exchangers, and plate-and-frame exchangers.
- Perform mass and energy balances for an evaporator.

- Propose actions to improve evaporation efficiency.
- Evaluate the economy and the useful temperature rise in an evaporator.
- Propose the most appropriate operating conditions for an evaporator.
- Know the most common evaporator configurations used in the chemical industry.
- Thermally size an evaporator.
- Know the fundamental laws governing thermal radiation.
- Evaluate the heat flux transmitted by radiation for a given application.
- Determine the temperature of a surface exchanging heat by radiation with the environment.
- Explain and define terms such as, thermal radiation, black body, grey body, emissivity, refractive surface, view factor.
- Understand the concept of view factor.
- Determine radiation exchange between black and refractive surfaces in an enclosure.
- Determine radiation exchange between grey and refractive surfaces in an enclosure, as well as between surfaces and gases.
- Identify the basic sections of boilers and furnaces.
- Estimate the heat flux transferred in a furnace or boiler.
- Provide an approximate sizing of furnaces.

3. PRIOR KNOWLEDGE AND RECOMMENDATIONS

Pre-requisite knowledge

Successful follow-up of this subject requires that the student has previously acquired the knowledge and competencies corresponding to the following subjects: Fundamentals of Chemical Engineering, Mathematics I, Mathematics II, Applied Thermodynamics, Fluid Mechanics. Although enrolment is not formally conditioned by such academic background, effective command of these subjects is essential to take this course with reasonable prospects of benefit.

Recommendations

It is recommended that the student has a basic level of English that allows them to handle English-language bibliography, perform information searches and communicate in writing and orally in that language. It is also recommended that the student is familiar with software tools for solving complex problems, as well as applications for drafting, editing and presenting technical reports.

4. CONTENTS

Brief Description

Conduction. Natural and forced convection. Phase change. Radiation. Heat exchangers. Evaporators and condensers. Energy sources: combustion. Furnaces. Steam boilers.

Course Syllabus

BLOCK 1. INTRODUCTION TO THERMAL ENGINEERING

Topic 1. Generalities. Introduction. Heat transfer mechanisms. Fundamental laws. Temperature measurement. Common heating and cooling agents.

BLOCK 2. HEAT TRANSFER BY CONDUCTION

Topic 2. Heat transfer by conduction. Fourier’s law: thermal conductivity. Energy conservation equation. Heat conduction through solids: one-dimensional and multidimensional. Transient heat conduction. Solving heat transfer problems by numerical methods.

BLOCK 3. HEAT TRANSFER BY CONVECTION

Topic 3. Heat transfer by convection I. Internal flow. Introduction. Individual heat transfer coefficients. Dimensional analysis. Entrance effects. Variation of physical properties with temperature. Laminar regime. Turbulent regime. Transitional regime. Non-circular cross-sections. Influence of natural convection. Non-Newtonian fluids. Liquid metals.

Topic 4. Heat transfer by convection II. External flow. Estimation of heat transfer coefficients in systems of simple geometry: flat plates, cylindrical bodies, spherical bodies. Estimation of heat transfer coefficients in systems of industrial interest: fixed beds, tube bundles. Heat transfer by natural convection.

Topic 5. Heat transfer with phase change. Introduction. Boiling of liquids on submerged surfaces. Boiling of liquids inside tubes. Condensation of vapours on vertical and horizontal surfaces.

BLOCK 4. HEAT TRANSFER EQUIPMENT

Topic 6. Heat exchangers. Basic concepts. Types of exchangers. Overall heat transfer coefficient. Fouling factor. Concentric-tube heat exchangers: basic design equation. Multi-tubular exchangers. Number of transfer units. Compact heat exchangers. Fins. Plate exchangers. General design considerations.

Topic 7. Heat integration. Pinch technology. Principles and objectives of Pinch analysis. Minimum heating and cooling requirements. Construction of composite curves. Pinch point. Problem table algorithm. Grand composite curve. Minimum number of exchangers. Design of heat-exchange networks.

Topic 8. Evaporation. Introduction. Design equation of an evaporator. Evaporator calculation. Energy utilisation: multiple effects, recompression. Types of evaporators.

BLOCK 5. HEAT TRANSFER BY RADIATION

Topic 9. Heat transfer by radiation I. Basic concepts. Nature of thermal radiation. Emission of radiation: black body, Planck's law, Stefan–Boltzmann law, emissivity. Reception of radiation: absorbance, reflectance and transmittance. Radiation transmission. Relationship between radiation intensity and incident radiative flux or emissive power. Kirchhoff's law: grey surfaces. Radiative properties of real surfaces. Environmental radiation.

Topic 10. Heat transfer by radiation II. Radiative energy exchange. Introduction. View factors. Enclosures of black surfaces. Enclosures of black and refractive surfaces. Enclosures of grey and refractive surfaces. Radiation exchange between surfaces and gases.

Topic 11. Furnaces. Introduction. Factors in radiative heat transfer. Heat receiver. Heat source.

5. COMPETENCES

General

CG1-MII1	Apply concepts of applied thermodynamics.
CG1-MII7	Use the principles of machines and mechanisms.

Specific

CE7-T12	Recognise the principles on which the different heat-transfer mechanisms are based.
CE7-T13	Design equipment based on heat transfer: heat exchangers, evaporators, and condensers.
CE7-T14	Design combustion-based energy-generating equipment: furnaces and steam boilers.
CE7-T15	Measure technical parameters in heat-transfer equipment and installations and interpret them technically.

Cross-cutting

CT2-II1	Demonstrate capacity for analysis and synthesis in Industrial Engineering.
CT3-II1	Organise and plan documents and projects in the field of Engineering.
CT5-II1	Consult, use and analyse bibliographic sources.
CT5-II2	Use bibliography, specialised databases and resources accessible through Internet.
CT6-II1	Use computer programs to calculate, design, simulate, approximate, and predict.
CT7-II1	Work in a team.
CT9-II1	Demonstrate professional ethical commitment.
CT10-II1	Integrate acquired knowledge and apply it to solving problems in Industrial Engineering.
CT11-II1	Learn autonomously.
CT13-II1	Demonstrate initiative and creativity in solving new situations.

6. WORKLOAD DISTRIBUTION BY ACTIVITY

Activity	In-class (hours)	Self-study (hours)	Credits
Theory classes	39	63,5	4,1
Seminars	21	36,5	2,3
Tutorials/guided work	4	6	0,4
Laboratory	25	17,5	1,7
Preparation of Course work and Exams	6	6,5	0,5
Total	**95**	**130**	**9**

7. METHODOLOGY

Teaching will follow a mixed methodology based on cooperative learning, collaborative learning and self-learning. This methodology will be developed through lectures, seminar classes, tutorials and directed work, as well as laboratory sessions.

Lectures will be delivered to a single group comprising all students enrolled on the subject. They will mainly consist of master classes in which the theoretical knowledge necessary to solve the practical examples seen during the course will be presented.

Seminar classes will be delivered in two groups, each formed by half of the students enrolled on the subject, or in a single group with the attendance of several teachers. These classes will address both the resolution of pre-assigned problems and some complementary, eminently practical topics. Part of these activities will be conducted in English. Software such as Matlab, Excel, Origin, etc., may be used to solve the problems. Training activities will be developed with practical exercises or case studies related to safety in chemical plants working with codes of good practice.

Tutorials and directed work will be carried out individually or in small groups of students enrolled on the subject. Tutorials will supervise students' progress in their personalised work, resolving their doubts. In tutorials and directed activities, necessary calculations may be performed using scientific software (Matlab, Excel, Origin). Tutorials and directed activities will include tasks that allow assessment of project capability using some cutting-edge knowledge in the Chemical Engineering speciality. Cases related to safety in chemical plants will be studied using codes of good practice.

Laboratory sessions will consist of experimental determinations where both general competencies (CG1-MII1, CG1-MII7) and specific competencies (CE7-T12, CE7-T15) will be developed, and results will be interpreted through the preparation of reports, in accordance with transversal competencies (CT2-II1, CT3-II1, CT5-II1, CT5-II2, CT6-II1 and CT7-II1). Questions will also be posed by the teachers during laboratory sessions. Part of these activities will be conducted in English. Necessary calculations will be performed using scientific software (Matlab, Excel, Origin). Prior to carrying out the laboratory work for the subject, the student must confirm in writing that they have read, understood and accepted the laboratory safety rules.

The **UCM Virtual Campus** will be used to provide students with the material used in lectures and seminars, and as a means of communication between teachers and students. Part of the recommended bibliography and supporting material deposited on the Virtual Campus for the development of teaching activities for this subject will be in English.

8. BIBLIOGRAPHY

Basic

- Kreith, F. y Bohn, M.S., "*Principles of Heat Transfer*", Harper & Row, 5ª Ed., New York, (1997). Ed. Castellano: "*Principios de transferencia de calor*", 6ª Ed., Ed. Paraninfo, Madrid, 2001.
- Incropera, F. P., De Witt, D.P., Bergman, T. L. y Lavine, A. S. (2018). "*Fundamentals of heat and mass transfer*", 8th Ed. John Wiley and Sons Inc., USA. Ed. Castellano: "*Fundamentos de la transferencia de calor*", Prentice Hall, 1999.
- Costa, E y col., "*Ingeniería Química 4. Transmisión de calor*", Alhambra, Madrid, 1986.

Complementary

- Holman, J.P., "*Heat Transfer*", McGraw-Hill, New York, 8ª Ed., 1997.
- Geankoplis, C.J., "*Transport processes and unit operation*", 4ª Ed., 2003.

9. EVALUATION

The student's academic performance and the final grade for the subject will be computed as a weighted average according to the following percentages, which will be maintained in all assessment calls.

To pass the subject, the student must obtain a final grade equal to or greater than 5 out of 10, considering the contribution of written exams (70%) and the rest of the formative activities (30%).

The final course grade will be calculated as the weighted average of the different assessable activities. However, to pass the course, students must obtain the minimum grade established for each activity. If this requirement is not met, the final grade will be the weighted average, capped at 4.5 out of 10. This criterion shall apply to both the ordinary and extraordinary assessment periods.

❖ WRITTEN EXAMS: 70%

Assessment of the competencies acquired in the subject (CG1-MII1, CG1-MII7, CE7-T12, CE7-T13, CE7-T14, CT2-II1 and CT10-II1) will be carried out by means of two written exams in the ordinary call in June and the extraordinary call in July, mainly practical in nature, which will represent 70% of the overall assessment. It will be necessary to obtain a minimum score of 5.0 out of 10 in the final exam for this activity to contribute to the overall grade for the subject. This criterion will be maintained in the extraordinary call.

❖ SELF-WORK AND GUIDED ACTIVITIES: 10%

The student's personal work will be assessed considering their skills in solving model problems through written tests or personalised submissions. This grade will be maintained for the extraordinary call.

Competencies assessed: CG1-MII1, CG1-MII7, CE7-T12, CE7-T13, CE7-T14, CT2-II1, CT3-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1, CT11-II1 y CT13-II1.

❖ LABORATORY SESSIONS: 20%

The ability to carry out experimental determinations and interpret the results will be assessed based on the reports prepared and the questions posed by the lectures in the laboratory.

Assessment will consider the quality of the technical report for each practical, answers to specific questions posed by the teacher during the laboratory sessions, the calculation files and a prior knowledge test (including laboratory safety rules).

Grades obtained by the student in the ordinary call for this part will be maintained in the extraordinary call.

Competencies assessed: CG1-MII1, CG1-MII7, CE7-T12, CE7-T15, CT2-II1, CT3-II1, CT5-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1 y CT13-II1.

Grades for activities planned for the assessment of the subject (laboratory sessions, tutorials, submission of problems, etc.) will be communicated to students with sufficient notice before the final exam, so that they can plan their study of this and other subjects appropriately.

In any case, a minimum period of seven days will be respected between the publication of grades and the date of the final exam of the subject.

Students who have carried out the laboratory sessions during previous academic years will have the option to request not to repeat them provided that no more than two years have elapsed since they were carried out.

In laboratory sessions, directed activities and tutorials, in addition to the corresponding report, the programmes/files of scientific calculations developed by the student in the preparation of results must be submitted.

ACTIVITY SCHEDULE

UNIT	ACTIVITY	HOURS	GROUPS	START	END
Block 1. Introduction to Thermal Engineering.	Theory classes	2	1	1st Week	
	Seminars	-	2		
Block 2. Heat transfer by conduction.	Theory classes	9	1	2nd Week	5th Week
	Seminars	5	2		
Block 3. Heat transfer by convection.	Theory classes	8	1	5th Week	8th Week
	Seminars	5	2		
Block 4. Heat transfer equipment.	Theory classes	10	1	8th Week	12th Week
	Seminars	6	2		
Block 5. Heat transfer by radiation.	Theory classes	10	1	12th Week	15th Week
	Seminars	5	2		
	Laboratory sessions	12,5	2	6th Week	7th Week
		12,5	2	12th Week	13th Week
	Tutorial*	4	4		

*The timetable for tutorials depends on the overall schedule of all the course modules.

SUMMARY OF ACTIVITIES

ACTIVITY	ASSOCIATED COMPETENCES	TEACHING ACTIVITY	STUDENT ACTIVITY	EVALUATION	P	NP	TOTAL	C
Theory classes	CG1-MII1; CG1-MII7 CE7-T12; CE7-T13; CE7-T14; CT2-II1; CT10-II1	Presentation of theoretical concepts necessary to solve practical cases	Note-taking. Computer use	Exam questions on the content presented in lectures	39	63,5	102,5	**70%**
Seminars	CG1-MII1; CG1-MII7 CE7-T12; CE7-T13; CE7-T14; CT2-II1; CT3-II1; CT5-II2; CT6-II1; CT9-II1; CT11-II1; CT13-II1	Solving practical case examples and advising students on assigned practical cases	Note-taking, computer use. Application of knowledge acquired in lectures	Grading of assigned practical cases, and exam questions on problem solving	21	36,5	57,5	**10%**
Tutorial	CG1-MII1; CG1-MII7; CE7-T12; CE7-T13; CE7-T14; CT2-II1; CT3-II1; CT5-II2; CT6-II1; CT7-II1; CT9-II1; CT11-II1, CT13-II1	Supervision of students' progress	Preparation of questions for the teacher, assimilation and application of explanations received	Assessment of student participation and interest	4	5	10	
Laboratory sessions	CG1-MII1; CG1-MII7; CE7-T12; CE7-T15; CT2-II1; CT3-II1; CT5-II1; CT5-II2; CT6-II1; CT7-II1; CT9-II1; CT13-II1	Supervision of correct handling of laboratory equipment	Conducting experiments, data collection and discussion of results	Assessment of laboratory report and questions raised during the practical	25	17,5	42,5	**20%**
Exams	CG1-MII1; CG1-MII7; CE7-T12; CE7-T13; CE7-T14; CT2-II1; CT10-II1	Preparation, invigilation and marking of exams. Grading the student	Study and sit the exam	Exam grade	6	6,5	12,5	

P: Presential activities

NP: Non-presential activities (independent work)

C: Contribution to final grade