Course Guide

Sceneries 1, 2, 3:

CHEMICAL ENGINEERING

CHEMISTRY DEGREE
COMPLUTENSE UNIVERSITY OF MADRID
ACADEMIC YEAR 2021-2022

SCENARIO1. ON-SITE

I.- IDENTIFICATION

COURSE NAME:	**Chemical Engineering**
CREDITS (ECTS):	**9**
CHARACTER:	**Compulsory**
SUBJECT:	**Fundamental Complements of Chemistry**
MODULE:	**Fundamental**
DEGREE:	**Bachelor in Chemistry**
SEMESTER/TERM:	**Second (second year)**
DEPARTMENT/S:	**Chemical Engineering and Materials**

LECTURERS:

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II.- OBJECTIVES

■ GENERAL OBJECTIVE

The general objective is to provide students with fundamental knowledges of the different areas in Chemical Engineering (unit operations, chemical reaction engineering and process engineering) that will allow them to understand the main operations and the fundamentals of the equipment that enable an industrial chemical plant to work. To provide the students the ability to assess the importance of chemistry in the industrial and environmental context.

SPECIFIC OBJECTIVES:

- To know the main milestones in the chemical industry, and the current situation of chemical industry in the world, Europe, and Spain.
- To understand the classic ways of exploitation in the chemical industry, the ways of operating and its objectives, as well as to understand what a raw material is and its main characteristics.
- To learn the underlying concepts of mass and energy balances, as well as the practical aspects for the resolution of problems based on the law of conservation of matter and energy.
- To be able to approach and solve steady state mass balance problems, both of isolated units and of several units connected to each other.
- To understand the concept of unit operation, as well as to know the main unit operations and the equipment in which they are carried out.
- To understand the nature of transport phenomena, and their relationship with unit operations. To know the different transport phenomena and their mechanisms.
- To know the objective of fluid dynamics, the concepts of fluid and flow and their types, and the proper use of Bernouilli’s equation, or the principle of conservation of mechanical energy, for incompressible fluids.
- To know the main elements constituting a pipe network: pumps, flow meters, pipes, and valves.
- To understand the different mechanisms of heat transfer and to solve simple problems related to conduction and convection phenomena.
- To understand the design equation for concentric-tube heat exchangers and its difference with those for industrial shell and tube, and plate heat exchangers. To solve problems of heat exchangers and evaporators focused on calculating the exchange area.
- To know the main operations based on the momentum exchange: sedimentation, centrifugation, filtration, and agitation. To understand the purpose and basis of each operation, and to know the equipment in which they operate and the differences among them.
- To know the fundamentals and applications of stage distillation, as well as the equipment to carried it out. To understand and apply the McCabe-Thiele method for designing basic rectification columns, and the main design parameters of this type of equipment.
- To understand the aim of Chemical Reaction Engineering, and its main tools to study reaction systems.
- To understand the differences between homogeneous and heterogeneous systems where chemical reactions occur. To know, from rate equations, the time evolution of compounds in homogeneous systems both with elemental reactions and reaction networks: equilibrium reactions, series and parallel reactions.
- To apply these concepts in the resolution of standard problems focused on the application of the differential and integral methods for the study of the kinetics of the reaction system.

- To understand and know the main concepts of reactions catalysed by solids and their relevance: importance of the transport phenomena, the most representative kinetic models, and the most relevant applications.
- To know the differences and similarities of the different types of ideal reactors, as well as to know how to design ideal isothermal reactors.
- To understand the difference between homogeneous and heterogeneous reactors, as well as to know the importance of the latter in the Chemical Industry.
- To know the processes and raw materials for the manufacture of ammonia.
- To know the processes and raw materials for the manufacture of sulfuric acid.
- To know the ways of exploitation of crude oil and natural gas.
- To learn the measures for the control and remediation of pollution.

III.- PREVIOUS KNOWLEDGE AND RECOMMENDATIONS

PREVIOUS KNOWLEDGE:

Inorganic and organic nomenclature and formulation. Stoichiometry. Unit conversion. Thermodynamics. Basic knowledge of inorganic and organic chemistry. Basic concepts of chemical kinetics.

RECOMMENDATIONS:

Having passed the subjects General Chemistry and Mathematics (Basic Subjects).

IV.- CONTENTS

BRIEF DESCRIPTION:

General concepts: continuous and discontinuous operations. Process flow diagrams. Material and energy balances. Chemical processes of industrial interest. Energy and environment. Unit operations. Fluid dynamics. Heat transfer. Mass transfer. Separation processes. Chemical reaction engineering. Applied chemical kinetics. Chemical reactors.

SYLLABUS:

SECTION 1 INTRODUCTION AND GENERAL CONCEPTS

Unit 1: Chemical industry and chemical engineering

Historical development of chemical processes and chemical industry in Spain. Structure of the chemical industry. Use of raw materials of inorganic and organic nature. Products and applications.

Unit 2: Basic concepts in chemical engineering

Stoichiometry (concept of mole, limiting reagent, conversion, yield, selectivity, stream composition). Study of the main variables in a chemical process and their unit conversions.

Unit 3: Concepts of operation and transport phenomena

Continuous and discontinuous operations. Steady and non-steady state regimes. Types of phases contact. Fundamentals and classification of operations. Molecular and turbulent transport. Basic transport equations. Transport coefficients.

SECTION 2 MACROSCOPIC MATERIAL BALANCES

Unit 4: Macroscopic balances of extensive magnitudes

General conservation equation. Mass and enthalpy balances. Resolution of practical cases of mass balances.

SECTION 3 FLUID DYNAMICS

Unit 5: Fluid dynamics

Definitions and classification. Laminar and turbulent regime. Fluid transport by pipes. Bernouilli's equation. Pumps, flow-meters and other accidents in pipelines. Fluid dynamics operations: agitation, filtration, sedimentation, and centrifugation.

SECTION 4 HEAT TRANSFER

Unit 6: Heat transfer

Mechanisms: conduction, convection, and radiation. Basic transport equations. Heat exchangers. Evaporation.

SECTION 5 MASS TRANSFER

Unit 7: Mass transfer

Diffusion and convection. Basic transport equations. Mass transfer operations: simple distillation and rectification.

SECTION 6 REACTION ENGINEERING AND REACTORS

Unit 8: Chemical reaction engineering

Classification of chemical reactions. Kinetic models: reaction schemes and reaction rate. Homogeneous and simple reactions: determination of kinetic models. Catalytic heterogeneous reactions: solid catalysts and phenomenology.

Unit 9: Chemical reactors

Classification: number of phases, type of operation and degree of mixing. Ideal reactors for homogeneous reactions: discontinuous (batch) reactor and continuous reactors. Heterogeneous reactors: description and applications.

SECTION 7 INDUSTRIAL CHEMISTRY

Unit 10: Ammonia as the main product of the Inorganic Chemical Industry

Processes and raw materials for the manufacture of ammonia. Ammonia applications.

Unit 11: Manufacture of sulfuric acid

Raw materials and processes. Metal sulphides as chemical industry raw material. Composition and characteristics. Pyrite roasting.

Unit 12: Use of crude oil and natural gas

Origin, composition, and characterization. Treatment of crude oil and its fractions. Refinery products. Basic petrochemical industry. Derived Industries.

Unit 13: Chemical industry and the environment

Types, origin, and characterization of pollution? Internal and external corrective actions. Minimization of waste and emissions. Purification, management and use of waste.

V.- COMPETENCES

GENERAL:

- **CG1-MF1:** To recognize and value chemical processes in everyday life.
- **CG2-MF1:** To link Chemistry with other fields of study.
- **CG3-MF1:** To progress their studies in multidisciplinary areas.
- **CG5-MF1:** To demonstrate the knowledge and understanding of essential facts, concepts, principles and theories related to Chemistry.
- **CG6-MF1:** To analyse and solve qualitative and quantitative problems.
- **CG7-MF1:** To recognise and analyse new problems and to design new solving strategies.
- **CG8-MF1:** To be able to look up and apply efficiently scientific information.

SPECIFIC:

- **CE30-MFCQ1:** To describe the most relevant processes in the chemical industry.
- **CE30-MFCQ2:** To value the importance of the effective planning and the development of chemical processes developed in the area of Chemical Engineering.
- **CE31-MFCQ1:** To explain and understand in a streamlined manner process flow diagrams of industrial processes, identifying the operations and main equipment of a chemical plant.
- **CE31-MFCQ2:** To formulate and solve the properties balances that describes how a system changes due to a disruption produced by mass and heat transfer.
- **CE31-MFCQ3**: To classify separation processes according to physical-chemical and thermodynamic principles that compose the industrial chemical process.
- **CE31-MFCQ4:** To describe the operation of chemical reactors and to value the importance of chemical kinetics in their design.

CROSS DISCIPLINARY:

- **CT2-MF1**: To work as a team.
- **CT3-MF1**: To demonstrate critical thinking and self-criticism.
- **CT5-MF1**: To correctly use chemical-related information, bibliography, and specialised databases.
- **CT6-MF1**: To identify the importance of chemistry within the industrial, environmental, and social framework.
- **CT11-MF1**: To develop self-learning skills.
- **CT12-MF1**: To identify the current energy concerns and their implications.
- **CT12-MF2**: To develop sensitivity to environmental topics.

VI.- LEARNING OUTCOMES

Having passed this course, the student must be able to:

- Differentiate lab-scale processes from industrial processes regarding to operational volume, yields, raw material employed, resources valorisation, presence of rate determining steps, etc.
- Describe the concept and overall methodology followed in Chemical Engineering, and its links with other scientific and technical fields.
- Understand in a streamlined manner process flow diagrams of industrial processes, identifying the main operations and equipment involved in a chemical plant.
- Formulate and solve mass balance exercises, involving (or not) chemical reactions in isolated process units, and simple processes with limited number of recycling and purge streams.
- Explain the importance of a chemical-physical industrial process, properly ordered unit operations, operational requirements in every unit operation, and the nature of every operation.
- Define the core aspects of underlying phenomena of every unit operation process which will determine the specific design of the unit process. Relate physical laws and empirical equations that describe phenomena with the equations employed in the design of some selected unit operations.
- Describe differences and similarities of different fluids and their flows, as well as the concept of viscosity and its physical meaning.
- Deduction of the mechanical energy conservation, so called Bernouilli's equation, and explain every parameter involved. Apply the Bernouilli's equation to straightforward systems, estimating every parameter and the pump power.
- Explain heat transfer and the mechanisms involved in this phenomenon. Apply and know empirical equations and the main mechanisms that enable to deduce flow rates and energy flow rates in simple geometries, as well as the corresponding temperature profiles.
- Design industrial double pipe heat exchangers applied to simple cases of study.
- Explain mass transfer (concept and mechanisms) and phase equilibria, especially fluid phase equilibria.
- Explain distillation processes as an example of unit operation based on liquid-vapor equilibrium as well as Raoult's and Dalton's laws.
- Design simple rectification columns for ideal and real binary systems using different kind of feed and applying McCabe-Thiele plot method to total and partial condensers using operational and extreme conditions in the rectification column.
- Apply general mass balances and volatiles mass balances in different sections and trays of a rectification column for a better understanding of McCabe-Thiele method.
- Explain the concept of chemical reaction Engineering, tools employed in the topic, and its importance in scale-up of chemical reactors.
- Define main concepts of applied chemical kinetics: reaction rates, variables involved, equations (models). Relate the reaction rates related variables and equations involved.

- Solve simple problems of applied kinetics: relation between unit constants and kinetics order, calculation of kinetic constants using differential and/or integral methodologies and calculation of activation energies.
- Design ideal chemical reactors: batch and continuous reactor, differentiate them qualitatively and quantitatively.
- Apply the concepts of: reaction time, dead time, and residence time.
- Describe the importance of different operations and processes used in the manufacture of ammonia, sulfuric acid, and refinery products.
- Differentiate the main characteristics of raw materials employed in the above-mentioned examples of processes within the chemical industry.
- Describe the different reactors and technologies employed in the above-mentioned examples of processes within the chemical industry.
- Explain the current environmental management problems that emerge from the chemical industry and similar industries in the environment. Explain the main technological processes available to avoid pollution or limit the undesirable side-effects of pollutants in the atmosphere, hydrosphere, lithosphere, and biosphere.

VII.- WORKING HOURS DISTRIBUTED BY ACTIVITY

Activity	Attendance (hours)	Self-study (hours)	Credits/ hours
Lectures	42	88	5.2
Seminars / Problem classes	24	26	2.0
Tutorials / Guided work	4	6	0.4
Practical activities	6	9	0.6
Written assignments and exams preparation	6	14	0.8
Total	**82**	**143**	**9**

VIII.- METHODOLOGY

The contents of the course are presented to the students through lectures, seminars, scheduled evaluation tests (tutorials), and practical activities.

Lectures will be master lessons in which the complete syllabus will be exposed. Some topics will include problem resolution. Audio-visual content will be employed in the development of the lesson for an optimal understanding of every topic. Schemes, tables, figures, and any other kind of resource will be available for the students in paper/computer format through the Virtual Campus.

Seminars will be sessions to solve selected exercises. A list of exercises will be given in advance so the student may solve them by his/her own.

Scheduled evaluation tests (tutorials) are the framework in which the student will develop and solve theoretical questions, practical questions, and numerical exercises. Tutorials will cover in every session some of the topics of the subject. The students will be informed in advanced about the dates and topics that will be evaluated in every tutorial.

Practical activities will be developed in small groups. A complete session will be dedicated to show videos of industrial processes, explaining different kind of pumps, flow meters, and other basic equipment used in industrial facilities. Another session will be employed to show the students some of the most employed software tools in Chemical Engineering.

"Campus Virtual" (CV) will be used to create a responsive communication between lecturers and students, as a tool to facilitate the material that is going to be taught during lectures and seminars. "Campus Virtual" will also be employed to provide some supplementary material that can be relevant in the course but not necessarily be presented during a class.

IX.- BIBLIOGRAPHY

At the beginning of the course, the recommended bibliography will be explained, pointing out the most relevant aspects of each book and how the contents fit the subject's topics. A specific textbook will not be followed during the development of the subject.

BASIC:

- Aguado, J. y *col.*: "*Ingeniería de la Industria Alimentaria"*, Ed. Síntesis, Madrid, 1999.
- Calleja, G. y *col.*: "*Introducción a la Ingeniería Química"*, Volumen I: Conceptos básicos. Ed. Síntesis, Madrid, 1999.

COMPLEMENTARY:

- Himmelblau D.M. "*Basic Principles and Calculations in Chemical Engineering*". 5th ed. Englewood Cliffs, N.J.: Prentice-Hall; 1989.
- Felder R.M., Rousseau R.W. "*Elementary Principles of Chemical Processes"*. 3rd ed. New York: John Wiley & Sons; 2000.
- Ruíz Palacín, J.: *"Problemas resueltos de balances de materia en estado estacionario"*, Ed. Prensas Universitarias de Zaragoza, 2009.
- Izquierdo, J.F., Costa, J., Martínez de la Ossa, E., Rodríguez, J., Izquierdo, M. *"Introducción a la Ingeniería Química: Problemas resueltos de balances de materia y energía"*, Ed. Reverté, 2011.
- Levenspiel O. "*Chemical Reaction Engineering*". 3rd ed. New York: John Wiley & Sons; 1999.
- Levenspiel O. "*Engineering Flow and Heat Exchange"*. New York: Plenum; 1986.
- MacCabe WL,y col. "U*nit Operations of Chemical Engineering*". New Yorketc.: McGraw-Hill; 1956.
- Vian Ortuño, Á.: "*Introducción a la Química Industrial",* 2ª ed., Ed. Reverté; Barcelona, 1994.

In addition to the basic and complementary bibliography, specific bibliography for each topic could be provided to the students.

X.- ASSESSMENT PROCEDURE

The academic performance and the competencies achieved by the students will be evaluated, considering two parts: the written exams accomplished and the student's personal work.

It is mandatory to attend all the programmed evaluation tests and practical activities (either individually or in small groups). In addition, the final evaluation will be dependent on the student's attendance of at least 70 % of lectures and seminars.

The student's academic performance and the final marks of the course will be computed in a weighted manner, considering the following percentages and aspects, which will be maintained in the ordinary and extraordinary calls.

- **WRITTEN EXAMS: 70%**

  The **exams** will consist of a group of long answer questions or/and questions about the direct application of the concepts learned during the course (theory questions) and resolution of problems.

  There will be a **partial exam** in the half of the term. Students obtaining a **minimum score of 4 out of 10 in the partial exam**, being necessary that a minimum of 4 out of 10 is obtained in each part of the exam (theoretical questions and numerical problems), may release this material for the final exam in the ordinary call. For these students, the total exam score will be the average between the mark obtained in the partial exam and the part of the subject evaluated in the final exam. The obtained exam mark will represent the 70% of the global evaluation of the subject.

  There will be two final exams, one of which will occur in the ordinary call and the other one in the extraordinary call. Both of them will be composed of all topics considered in the syllabus of the subject.

  In the final exam of both calls, a minimum score of 4 out of 10 (4/10) in each part of the exam will be a prerequisite (theory and exercises) for averaging the remaining activities (practical activities and evaluated programmed tests).

  The written exam will evaluate the general competences, CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1; the specific competences CE30-MFCQ1, CE30-MFCQ2, CE31-MFCQ1, CE31-MFCQ2, CE31-MFCQ3, CE31-MFCQ4, and cross-disciplinary competences CT3-MF1, CT5-MF1, CT6-MF1, CT12-MF1, CT12-MF2.

- **SCHEDULED EVALUATION TESTS (TUTORIALS): 20%**

  During the course, there will be **four individual scheduled evaluations tests (tutorials)** in which the student will develop self-work, which may include theoretical questions, open practical exercises, and numerical problems that must be handled and solved. These questions will fulfil a specific number of units in each tutorial. The units and dates will be previously informed to the students.

The students will keep the marks obtained in the evaluation exercises in both ordinary and extraordinary calls.

The marking of these exercises will serve to evaluate the achievement of the general competences CG1-MF1, CG2-MF1, CG3-MF1, CG6-MF1, CG7-MF1, CG8-MF1, specific competences CE30-MFCQ2, CE31-MFCQ1, CE31-MFCQ2, CE31-MFCQ3 and cross-disciplinary competences CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT11-MF1, CT12-MF1, CT12-MF2.

- **PRACTICAL ACTIVITIES: 10%**

  Attendance at all practical activities is **compulsory** and will be evaluated by a questionnaire where the concepts explained in these sessions will be asked. These activities will be beneficial to improve the acquired knowledge acquired during the lectures, seminars, and other programmed activities. The latter will mean the achievement of the general, specific, and cross-disciplinary competences.

  The students will keep the marks obtained in the evaluation exercises in both ordinary and extraordinary calls.

The marks obtained in the scheduled activities (scheduled evaluation tests, practical activities) will be communicated to the students soon enough before the final exam to let the students adequately plan the study of this or other subjects.

In any case, a minimum of seven days between the publication of the marks and the date of the final exam will be scheduled.

ACTIVITY SCHEDULE

UNIT	ACTIVITY	HOURS	GROUPS	START	END
1. Chemical industry and chemical engineering	Lectures	1	1	1st week	1st week
2. Basic concepts in chemical engineering	Lectures and Seminars	4	1	1st week	1st week
3. Concepts of operation and transport phenomena	Lectures	4	1	2nd week	2nd week
4. Macroscopic balances of extensive magnitudes	Lectures and Seminars	10	1	2nd week	6th week
5. Fluid flow	Lectures and Seminars	8	1	3th week	5th week
6. Heat transfer	Lectures and Seminars	7	1	5th week	7th week
7. Mass transfer	Lectures and Seminars	7	1	7th week	8th week
8. Chemical reaction engineering	Lectures and Seminars	8	1	9th week	10th week

UNIT	ACTIVITY	HOURS	GROUPS	START	END
9. Chemical reactors	Lectures and Seminars	7	1	10th week	12th week
10. Ammonia as the main product of the Inorganic Chemical Industry	Lectures	2	1	12th week	12th week
11. Manufacture of sulfuric acid	Lectures	2	1	12th week	13th week
12. Use of crude oil and natural gas	Lectures	4	1	13th week	14th week
13. Chemical industry and the environment	Lectures	2	1	14th week	14th week
TUTORIAL AND PRACTICAL ACTIVITIES					
Scheduled evaluation tests	Test 1	1	1	4th week	4th week
	Test 2	1	1	7th week	7th week
	Test 3	1	1	9th week	9th week
	Test 4	1	1	13th week	13th week
Practical activities	2 practical activities	6	2	14th week	14th week

SUMMARY OF ACTIVITIES

Teaching activity	Associated competences	Lecturer activity	Student activity	Assessment procedure	P	NP	Total	C
Lectures	CG1-MF1, CG2-MF1, CG3-MF1 CG5-MF1 CE30-MFCQ1 CE30-MFCQ2 CE31-MFCQ3 CE31-MFCQ4 CT6-MF1 CT12MF1 CT12-MF2	Presentation of theoretical concepts and approach of problems.	Attention and active participation in the development of the class.	Written exams.	42	88	130	
Problem-solving classes /Seminars	CG6-MF1, CG7-MF1 CE31-MFCQ1 CE31-MFCQ2 CE31-MFCQ4	Approach and resolution of exercises and problems.	Discussion and resolution of the proposed questions and problems.	Assessment of the answers (approach and result) given for the resolution of practical exercises and numerical problems.	24	26	50	20%
Programmed tutorial and guide activities.	CG1-MF1, CG2-MF1, CG6-MF1, CG7-MF1, CG8-MF1 CE30-MFCQ2 CE31-MFCQ1 CE31-MFCQ2 CE31-MFCQ3 CT2-MF1 CT3-MF1 CT5-MF1 CT6-MF1 CT11-MF1	Statement of numerical exercises in the tutorials. Direction and supervision of the study and activities of the students.		Assessment of active participation of the work carried out.	4	6	10	

Teaching activity	Associated competences	Lecturer activity	Student activity	Assessment procedure	P	NP	Total	C
Practical activities.	CG1-MF1, CG2-MF1, CG6-MF1, CG7-MF1, CG8-MF1 CE30-MFCQ2 CE31-MFCQ1 CE31-MFCQ2 CE31-MFCQ3 CT2-MF1 CT3-MF1 CT5-MF1 CT6-MF1 CT11-MF1	Activity approach. Direction and supervision of the study and activities of the students.	Attention and development of the proposed activities.	Questionary marking.	6	9	15	10%
Examinations	CG1-MF1, CG2-MF1, CG5-MF1, CG6-MF1, CG7-MF1 CE30-MFCQ1 CE30-MFCQ2 CE31-MFCQ1 CE31-MFCQ2 CE31-MFCQ3 CE31-MFCQ4 CT3-MF1 CT5-MF1 CT6-MF1 CT12-MF1 CT12-MF2	Exam design. Surveillance and correction. Evaluation of the student.	Exam preparation and examination	Exam marking.	6	14	20	70%
P : In-class; NP: Self-study; C: Evaluation								

SCENARIO 2. MIXED

VIII.- METHODOLOGY

- Lectures **and seminars** will be carried out by the professors following Scenario 1. Following the safety guidelines of the Rectorate based on maximum assistance while keeping social distance, a maximum on site capacity will be defined for the lecture room. If the number of attendants exceeds this capacity, rest of the students will follow the teacher' lectures in streaming mode, either from their homes or in the appropriate spaces provided by the Faculty, which will be published in the CV. The students who follow the course in online mode will have available synchronous tools, such as Microsoft Teams or Google Meet. The teacher will open one session to maintain a direct communication with these students. A weekly rotatory shift based on ID number will be established to define which students attend on site and which ones attend on-line. This procedure will be adjusted during the year according to the percentage of class occupation.

    — The teaching material used will be the lecture presentations uploaded in the CV and employed in the Scenario 1. In addition, any supplementary material (as videos or presentations) considered of relevance by the teachers will be also uploaded into the CV.
    — The streaming tools used for the on-line teaching will be Microsoft Teams, Google Meet, or ZOOM. The teacher will be responsible for opening and keeping an opened online session to allow that the students attending on-line can follow the projector presentation or the explanation in the blackboard.

- **The practical laboratory courses** are planned to be implemented with a 60 % of occupancy to be able to keep the required social distance. According to the specifications of each session, the occupancy percentage might be slightly modified. The organization of the practical course teaching is based on the following characteristics:
    — It will be implemented according of one (or combination) of the following situations:
      (a) On-site in one lecture room with social distance.
      (b) On-line with synchronous sessions.
      (c) On-line with asynchronous sessions.
    — The teaching material will be the same than used in Scenario 1. Additionally, written material consisting in manuals, numeric exercises, graphs, or power point presentations supported by explanations.
    — All teaching material will be uploaded and made it available to the students in advance.

- **Individual Tutorial.**
  They will be implemented online by video-call or solved by email depending on the case.

- **Academic monitoring/tracking of students.**
  When online-teaching is implemented, monitoring will be the same as Scenario 1.
  When online teaching is used, diverse techniques will be approached: on-line tracking tools of the CV, attendant list of Google Meet, on-line form…

X.- EVALUATION

On site exams will be implemented as in Scenario 1.

SCENARIO 3. FULLY ONLINE

VIII.- METHODOLOGY

- **Theory teaching and seminars** will be taught by the combination of (a) Synchronous (same time that official teaching) and (b)Asynchronous sessions.
  - The teaching material used will be the lecture presentations uploaded in the CV and employed in the Scenario 1 and 2. The lectures presentations will be supplemented with audio to contain the same explanations that would be used in an on-site teaching. In addition, any supplementary material (as videos or presentations) considered of relevance by the teachers will be also uploaded into the CV. Material will be uploaded in the CV in advance.
  - The streaming tools used for the on-line teaching will be Microsoft Teams, Google Meet, or ZOOM.
- **The practical laboratory courses** will be implemented as in the Scenario 2 by exchanging the on-site sessions by: supply of tutorials consisting of written material, explanation of procedures, videos of similar experiences to ensure the acquisition of the Skills and Competences.

- **Individual Tutorials** will be implemented as in the Scenario 2.

- **Academic monitoring/tracking of students** will be implemented as the online session of the Scenario 2

X.- ASSESMENT PROCEDURE

DESCRIPTION OF THE ASSESMENT PROCEDURE

- **Identification of Students,**

Some minutes before the start of the exam, the students must deliver a signed letter of commitment (signed by hand and digitalized into a PDF document) accepting the rules of the execution of the exam. The body and text of the document, prepared by the Department, will be made available into the CV. In that document the name it must be indicated: name, surnames, signature, place and copy of the ID (DNI). Identification of the students will be performed by: (i) log-in in the CV to visualize the exam, (ii) image through Google Meet or Microsoft Teams, (iii) letter of commitment, and (iv) online tracking during the duration of the exam.

- **Type of exam.**

Exam will be designed in the CV (Moodle) by using the Task ("Tareas") tool, in that way different students can access to different variations of the exam.

The exam will be divided in two parts. In the first part (45 minutes of duration) will consist of two theory questions extracted from the question library, in that way questions will be different between students. In the second part (90 minutes duration), the students will solve numeric problems presented sequentially in the CV.

- **Monitoring of students during the exam.**

During the exam, the students must have connected a camera (computer or mobile phone) to allow the checking of the professor according to the letter of commitment previously signed by the student.

- **Post-exam review.**

The students who wish to have a post-exam review will contact the responsible professors by email. A review schedule will be established. To facilitate the post-exam review, each student must keep the original manuscript of the exam until the final publication of the marks. Once the marks have been published, each teacher will set a period for the online review of the exam. This review will be individual, at the student's request, and will be carried out using the connection tools currently available in the Virtual Campus.

- **Methods used for the documentation/recording of the evaluation procedure for their future visualization and evidence:**

The professor will keep the files (with the specified format) of the exam documents submitted by the student with the marks/grades. Moreover, if considered the exam could be recorded following the UCM restrictions, for further review. This record will only be saved with the required safety procedures into UCM devices and will be deleted after the post-exam review.