UNIVERSITY OF L'AQUILA

Department of Industrial and Information Engineering and Economics

2^{nd} Cycle Degree in CHEMICAL ENGINEERING

Laurea Magistrale in INGEGNERIA CHIMICA

Course Catalogue

Academic year starts the last week of September and ends the first week of June.
1^{st} Semester - *Starting date:* last week of September, *end date*: 3^{rd} week of January
2^{nd} Semester - *Starting date:* last week of February, *end date:* 1^{st} week of June
Exams Sessions: I) from last week of January to 3^{rd} week of February, II) from 2^{nd} week of June to end of July, III) from 1^{st} to 3^{rd} week of September

Comprehensive Scheme of the Second Cycle Degree in CHEMICAL ENGINEERING				
YEAR	**CODE**	**COURSE**	**Credits (ECTS)**	**Semester**
I	I0738	Analysis of Chemical Engineering Systems	6	1
	I0740	Safety in Process Plant Design	9	1
	I1H005	Chemical Process Analysis and Control	9	2
	I2H009	Chemical Engineering Principles II	6	2
	I0291	Chemical Reaction Engineering	9	2
		One elective course within the following:		
	B2F020	Biomaterials	6	2
	I0317	Biochemical Reaction Engineering	6	1
	I0739	Chemistry of Surfaces and Interfaces	6	1
		Free choice Courses	9	1/2
	I0592	*English Level B2*	3	3
II	DG0004	Industrial Bioprocesses	9	1
	I2H014	Chemical Plants II	6	1
	I2H026	Industrial Chemistry	9	2
	I0305	Corrosion and Materials Protection	9	2
	I0726	Laboratory of Chemical Engineering	3	2
		One elective course within the following:		
	I0301	Design and Process Analysis of Environmental and Biochemical Processes	9	1
	I0593	Science and Technology of Materials II	9	1
	I2HAT0	*Other Activities*	6	1/2
	I2HPF0	*Thesis*	18	2

Programme of "SICUREZZA NELLA PROGETTAZIONE DEGLI IMPIANTI DI PROCESSO" ***"SAFETY IN PROCESS PLANT DESIGN"***		
I0740, COMPULSORY **2^{nd} Cycle Degree in CHEMICAL ENGINEERING, 1^{st} year, 1^{st} semester**		
Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)		
Teacher : Giuseppe FUMAROLA		
1	Course objectives	The Module provides the students with knowledge, awareness and capacities enabling them -to analyze any chemical process problem with an integrated approach to the technical, social and economic aspects, -to compare the best available technologies and identify the most suitable for the case to solve with particular attention to the safety and the environmental impact, -to select and design in safety the unit equipments and auxiliaries.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: - Risk analysis: process hazard identification (checklists, safety review, relative ranking, hazop, what-if, fmea), risk assessment (event trees, fault trees, probability theory, human reliability), consequences analysis (source models, dispersion models, fires and explosions), risk evaluation, risk perception. - Risk prevention (design of inerting system, ventilation, relief systems, chimneys and flares, storage tanks). - Economic and engineering principles (cost of equipments, estimation of capital investment, optimum design and applications). - Special topics: air pollution and end-of-pipe technologies, wastewater treatments, waste treatments and disposal, approach to land-remediation. On successful completion of this module, the student should: o have profound knowledge of risk analysis; o acquire knowledge and understanding of the design-project procedures; o be able to apply knowledge and understanding in designing process equipments and auxiliaries; o demonstrate knowledge and understanding of the complexity of a chemical plant; o be able to make informed judgments and choices on the best available technologies; o be able to understand and explain choices among the best available technologies; o demonstrate skill in perform qualitative flow diagram and ability to design the main units and evaluate the investment; o demonstrate capacity for reading and understanding other interdisciplinary texts on related topics, international standards, laws and regulations for chemical process at risk; o be able to transfer and apply knowledge and understanding in evaluating safety and environmental impact; o acquire capacities to continue learning mainly on the field of risks in chemical processes.
3	Prerequisites and learning activities	To benefit from the course, students must know basic transport phenomena and unit operation fundamentals.
4	Teaching methods and language	Lectures, exercises, home work Language: Italian/English (when required by students) Ref. Text books: - Presentations prepared by the Teacher; - D.A. Crowl, J.F. Louvar, *Chemical Process Safety: Fundamentals with Applications*, Prentice Hall, 1990 - M.E. Peters and K.D. Timmerhaus, *Plant Design and Economics for Chemical Engineering*, McGraw-Hill Int. Ed., New York, 1991
5	Assessment methods and criteria	Exposition and discussion of a written thesis

Programme of "DINAMICA E CONTROLLO DEI PROCESSI CHIMICI" ***"CHEMICAL PROCESS ANALYSIS AND CONTROL"***
I1H005, COMPULSORY **2^{nd} Cycle Degree in CHEMICAL ENGINEERING, 1^{st} year, 2^{nd} semester**

Number of ECTS credits: 9 (workload is 225 hours; 1 credit = 25 hours)		
Teacher : Franco EVANGELISTA		
1	Course objectives	The Module provides the students with knowledge and understanding of dynamic models and control configurations for chemical processes. Students will be able to design and validate feedback, feedforward and advanced control schemes for multiple variables chemical processes.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: - Dynamic models: continuous stirred tank heater, heat exchangers, flash and counter-current stage operations, continuous contact operations.Transfer function (TF), autoregressive(ARX), and state-space (SS) models. - Feedback controllers: analysis, design, stability, and validation of feedback control loops. Advanced control Systems: long dead time and inverse response processes; multiple loop, selective, inferential, cascade , feedforward and feedforward-feedback. Multiple input and output systems, interaction and decoupling of control loops. digital control: converters, configurations, stability, feasibility, and responses. - State estimation and control: Kalman filter, pole placement and optimal regulators. Adaptive control: model reference adaptive control, self tuning regulator. On successful completion of this module, the student should: - have profound knowledge of chemical process dynamics; - have knowledge and understanding of fundamentals and advanced control schemes; - understand and explain the behavior of controlled and uncontrolled processes; - demonstrate skill in developing control configuration and ability in their design; - demonstrate capacity for their validation.
3	Prerequisites and learning activities	The student must have knowledge acquired in the first degree cycle and technical calculations.
4	Teaching methods and language	Lectures, exercises, and optional home work, team work. Language: Italian Suggested Text books -G. Stephanopoulos, *Chemical Process Control: An Introduction to Theory and Practice*; Prentice-Hall International Editions, Englewood Cliffs 1984. -W. L. Luyben M.L. Luyben, *Essentials of Process Control,* McGraw-Hill Book Company, New York,1997. -Dale E. Seborg, Thomas F. Edgar, Duncan A. Mellichamp, *Process Dynamics and Control*, 2° Edition, Wiley 2006.
5	Assessment methods and criteria	Oral exam, written exam or short report

Programme of “PRINCIPI DI INGEGNERIA CHIMICA II” “*CHEMICAL ENGINEERING PRINCIPLES II*”		
Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)		
I2H009, COMPULSORY **2nd Cycle Degree in CHEMICAL ENGINEERING, 1st year, 2nd semester**		
Teacher: Gabriele DI GIACOMO		
1	Course objectives and Learning outcomes	The course has the objective of forming chemical engineering students with the fundamental knowledge of the momentum, heat, and mass transfer in multi-phase multi-component systems. Equations of momentum, energy, and mass conservation are obtained as local and macroscopic balances. Constitutive equations (Newton, Fourier, and Fick) are used for obtaining velocity, temperature, and concentration profiles in laminar flow and different geometries. Friction factor and heat and mass transfer coefficients are defined in turbulent flow and in multi-phase and multi component systems and different geometries. Dimensionless numbers are defined and used. Heat and mass transfer coefficients at high mass transfer rates are derived by boundary-layer theory. At the end of this module the students will be able to simulate the momentum, heat and mass transfer in multi-phase and multi-component systems.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of this Module include: - Momentum, heat, and mass transfer in multi-phase multi-component systems. - Equations of momentum, energy, and mass conservation obtained as local and

		macroscopic balances. - Constitutive equations (Newton, Fourier, and Fick) for obtaining velocity, temperature, and concentration profiles in laminar flow and different geometries. - Friction factor and heat and mass transfer coefficients in turbulent flow and in multi-phase and multi component systems and different geometries. - Dimensionless numbers. - Heat and mass transfer coefficients at high mass transfer rates derived by boundary-layer theory. - Conservation laws and constitutive equations; mathematical formulations and calculation; pressure drop versus flow rate; heat and mass transfer coefficients. On successful completion of this module, the student should o have profound knowledge and understanding of transport phenomena in multi-component and multi-phase systems; o have ability to express such phenomena in mathematical form; o demonstrate skills in calculating transport properties, friction factor and heat and mass transfer coefficients; o demonstrate skills in solving problems on momentum, heat and mass transfer; o demonstrate capacity to work with a multidisciplinary team and to respect diversity; o be able to make autonomous choices, judgments and comparison of the different adopted solutions; o acquire capacity to assess the work and adjust the methodology.
3	Prerequisites and learning activities	The student must know the fundamentals chemical engineering thermodynamics.
4	Teaching methods and language	Lectures, exercise, laboratory experiments, computer modelling, home work. Language: Italian or English Ref. Text books -R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot, *Transport phenomena* (2nd ed.), John Wiley, 2002.
5	Assessment methods and criteria	Written exam and Oral exam

Programme of "REATTORI CHIMICI"
"*CHEMICAL REACTION ENGINEERING*"

I0291, COMPULSORY **2nd Cycle Degree in CHEMICAL ENGINEERING, 1st year, 2nd semester**		
Number of ECTS credits: 9 (workload is 225 hours; 1 credit = 25 hours)		
Teacher: Prof Pier Ugo FOSCOLO		
1	Course objectives	The course aims to provide the students with knowledge and understanding of the importance of fluid-dynamics in designing real reactors with major consideration of the influence of mass transfer on the overall kinetics (final conversion and yield) in multiphase reactors. Taking advantage of various numerical exercises, the students will be able to apply the concepts acquired to the industrial reactor design and to use simplified approaches to take decisions on the modeling choices to finalize the reactor design. The students will also gain the ability to evaluate the importance of employing different chemical reactors for the selectivity of the chemical processes, for the energetic efficiency, and for environmental impact.
2	Course content and Learning outcomes (Dublin descriptors)	List of Module's Topics: - Homogeneous reactors: definition of the reaction rate – molar conversion – balance equations utilized for reactor sizing – Damkoehler number – ideal reactors, continuous (tubular and stirred tank) and batch in isothermal operating conditions. multiple ideal reactors to model and design real reactors (residence time distribution functions are dealt with in a different course unit) – methodologies for kinetic analysis and evaluation of kinetic parameters – multiple reaction systems: series and parallel reactions, a generalised standard method to evaluate the performance of multiple reactions systems – complex kinetic expressions. Design of non isothermal reacting systems in continuous and batch operating conditions. Runaway exothermic reacting systems and safety measures.

		- Heterogeneous reactors: mass transfer coupled with chemical kinetics – external mass transfer (resistances in series) and *internal* diffusion (reaction efficiency and diffusion enhancement concepts). Shrinking core model. Analysis of gas/solid catalytic systems and gas/liquid and gas/liquid/solid reacting systems. Fixed bed reactors. - Elements of fluidization: two phase theory of fluidization – fluidized bed chemical reactor models. The topics related to mass and energy balances, reactor sizing, kinetics of gas-solid catalytic reactions, gas-liquid reactors, fluidized bed reactors are dealt with in details, also with the help of laboratory demonstrations. On successful completion of this module, the student should: o have extensive knowledge of homogeneous and heterogeneous reacting systems; o be able to apply knowledge and understanding to sizing of homogeneous and heterogeneous chemical reactors; o be able to make informed judgments on process alternative layouts and control policies of chemical reactors; o demonstrate skill in reactor design and ability to operate them; o demonstrate capacity to continue learning from scientific literature on chemical reaction engineering and related topics.
3	Prerequisites and learning activities	To gain the best benefit from the course, the students must possess a basic knowledge in chemical thermodynamics, unit operations, transport phenomena, and applied physical chemistry.
4	Teaching methods and language	Lectures, numerical exercises, lab demonstrations, home work, report Language: normally Italian, English when required by students Ref. Text books -H. Scott Fogler "*Elements of Chemical Reaction Engineering*" Prentice Hall Int, -Reports purposely prepared and distributed by the teacher
5	Assessment methods and criteria	Oral exam, including discussion of a short report prepared by the student on 2 lab demonstrations and 1 reactor sizing numerical exercise

Programme of "BIOMATERIALI"
"BIOMATERIALS"

B2F020, OPTIONAL
2nd Cycle Degree in CHEMICAL ENGINEERING, 1st year , 2nd semester

Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)

Teacher: Leonardo PAJEWSKI

1	Course objectives and Learning outcomes	This Module has the objective of presenting the particular materials used in contact with biological systems, named biomaterials, and their application in medicine. On successful completion of this module, the student should understand the fundamental concepts of biofunctionality, biocompatibility and sterility of a medical device.
2	Dublin descriptors	Topics of the module include: - Biocompatible materials for biotechnological applications. Use of materials in medicine in the past centuries. Concepts of biomaterial and biocompatibility. Regulations and Ethics. Biofunctionality and sterility requirements. - Classes of biomaterials: metallic, ceramic and polymeric. Surface properties of materials. Surface interactions with the water and with the proteins at the interface material-tissue. Modifying the surface properties of materials. - Biomaterials control specified by ISO 10933. Registration of medical devices and requirement of the CE marking in conformity with the Directive EC 93/42. - Evolution of biomaterials and tissue engineering applications. On successful completion of this module, the student should o understand biofunctional and biocompatibility requirements of a material used to carry out a medical device o understand surface interactions of a biomaterial with biological environment and the way to surface properties improvement o understand the quality control requirements defined by the Directive EC 93/42.
3	Prerequisites and learning	The student must know the basic concepts of Chemistry and Material Science.

	activities	
4	Teaching methods and language	Lectures, team work, home work Language: Italian Ref. Text books -B.D. Ratner, A.S. Hoffman, F.J Schoen, J.E. Lemons, *"Biomaterials Science. An Introduction to Materials in Medicine"*. Academic Press 2004. ISBN 0-12-582463-7. -R. Pietrabissa, *"Biomateriali per Protesi e Organi Artificiali*", Patron Editore, Bologna 1996.
5	Assessment methods	Seminar presentation and discussion of a medical device.

Programme of "PRINCIPI DI INGEGNERIA BIOCHIMICA"
"BIOCHEMICAL REACTION ENGINEERING"

I0317, OPTIONAL
2nd Cycle Degree in CHEMICAL ENGINEERING, 1st year, 1st semester

Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)

Teacher: Alberto GALLIFUOCO

1	Course objectives	This Module aims to equip the students with knowledge, understanding and ability to: -identify, model, and solve problems of biochemical reaction engineering which commonly arise in the industrial bioconversions; -develop the basic comprehension of the interactions between mass transfer and applied enzyme kinetics; -exploit their previous knowledge in basic chemical engineering for identifying analogies useful for modeling industrial bioreactors.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: - Enzyme kinetics. Mechanisms of inhibition and deactivation. Complex kinetics. Ideal enzymatic reactors: batch, plug-flow, CSTR, membrane bioreactors. - Analysis of stability: enzymatic CSTR. Enzyme and cells immobilizations: techniques, fundamentals, criteria of applicability. - Immobilization yield and activity recovery. - Transport phenomena coupled to heterogeneous biochemical reactions. - Thiele modulus, Damkhöler number, effectiveness factor. - Estimate of effective diffusivity. - Discrimination of the controlling step. - Apparent and intrinsic kinetics. - Heterogeneous enzymatic reactors: UF membrane, fixed bed, CSTR, batch. - Oxygen transfer to bioreactors: bubble fluid dynamics, effects of transfer rate on microbial growth. - Scale-up criteria for aerated bioreactors. On successful completion of this module, the student should: Expected results at the end of the course: o acquire knowledge and understanding on the phenomena occurring in bioreactors; o have profound knowledge of basic heterogeneous biocatalysis; o have knowledge and understanding of complex phenomena occurring during bioconversions; o have capacity to understand and explain bioreactor performances; o be able to apply knowledge and understanding for solving the mass balances in different enzymatic reactors; o be able to make informed judgments and choices on the operational conditions which could assure the highest yields of bioconversions; o demonstrate skill in model bioreacting systems and ability to solve the resulting equations; o have ability to communicate knowledge and understanding, mainly in multidisciplinary environments; o demonstrate capacity for reading and understanding other interdisciplinary texts on related topics and to continue learning in the field of industrial bioprocesses:
3	Prerequisites and learning activities	To benefit from the course, students should know chemistry and organic chemistry fundamentals, and basic transport phenomena. A elementary knowledge in biology would be

		advantageous, although not essential.
4	Teaching methods and language	Lectures, exercises, home work Language: Italian/English (when required by students) Ref. Text books: -Notes prepared by the Teacher; -Bailey & Ollis "*Biochemical Engineering Fundamentals"*, McGraw-Hill -Segel *"Enzyme Kinetics"*, Wiley
5	Assessment methods and criteria	Oral exam.

<table>
<tr><td colspan="3" align="center">Programme of “CHIMICA DELLE SUPERFICI E DELLE INTERFASI”
“CHEMISTRY OF SURFACES AND INTERFACES”</td></tr>
<tr><td colspan="3">I0739, OPTIONAL
2nd Cycle Degree in CHEMICAL ENGINEERING, 1st year, 1st semester</td></tr>
<tr><td colspan="3" align="center">Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)</td></tr>
<tr><td colspan="3">Teacher: Giulia FIORAVANTI</td></tr>
<tr><td>1</td><td>Course objectives</td><td>The goal of this course is to give candidates the fundamental knowledge of physical/chemistry of interface phenomena. Specific objectives are the principles and the application of different characterization techniques and the principles of surface functionalization.
On completion of this course, students will be able to demonstrate an awareness of the importance of processes that occur at interfaces, and to give examples of the applications of surface chemistry and the functionality of materials.</td></tr>
<tr><td>2</td><td>Course content and Learning outcomes (Dublin descriptors)</td><td>Topics of the module include:
- Introduction on the states of matter. The gaseous state. The condensed states: solid, liquid.
- The technique of vacuum. Vacuum levels; Ultra High Vacuum (UHV).
- Fundamentals of surface phenomena. Type of interphases and its features. Surface tension: determination in liquids and solids. Elements of thermodynamics of surfaces and interfaces. Surface free energy and stability. Phenomena of adhesion and cohesion. Surface effect: Laplace-Young equation.
- Models of interphase. The surface phase approach The excess surface approach: the Gibbs surface.
- Adsorption. Physical and chemical adsorption. Adsorption models: isotherms (BET). Chemisorption. Adsorption from solution. Amphiphilic adsorption.
- Solid-liquid interaction. Contact angle and wettability: Young-Dupré equation. Surface tension measurements. Hysteresis. Surface roughness. Wenzel Cassie.
- Surfaces Characterization Techniques. Structural characterization: morphology, defects, thickness.
- Microscopic Characterization. Optical and Fluorescence microscopy. Electron microscopy (TEM, SEM). Scanning Probe Microscopy (STM). Atomic force microscopy (AFM).
- Spectroscopic characterization. UV-Visible Spectroscopy. IR-Raman spectroscopy. X-ray photoemission spectroscopy (XPS). Auger electron spectroscopy (AES).
- Modification of surfaces. Deposition of thin and thick films. Physical Vapor (PVD) and Chemical Vapor Deposition (CVD). Deposition from solution. Drop casting, spin coating, dip coating and Langmuir- Blodgett films. Lithographic techniques: Photolithography and Soft-lithography.
- Self -assembled monolayers (SAM). Formation and properties. Defects, stability and reproducibility. SAM of thiols and silanes. Cleaning and activation of surfaces. Chemical gradients on surface: wettability gradients.

On successful completion of this module, the student should:
o have profound knowledge of the concept of surface energy to study capillary phenomena; adhesion and cohesion; wetting,
o have knowledge and understanding of physical and chemical adsorption at interfaces solid/gas and solid/liquid,
o recognize properties of the interface between two different material phases and understand the chemical processes that occur at such interfaces
o understand and explain surface analysis at the micro- and nano-scale,
o understand the fundamentals of vacuum techniques,</td></tr>
</table>

		o have profound knowledge of thin films and self-assembling monolayers, o demonstrate skill in surface cleaning protocols and ability to modify surface properties. o demonstrate capacity for reading and understanding other texts on related topics.
3	Prerequisites and learning activities	The student must know the basic knowledge of General and Inorganic Chemistry and Chemical Thermodynamics.
4	Teaching methods and language	Lectures, laboratory experiments. Language: Italian/English Ref. Text books -J. C. Berg, "*An Introduction to Interfaces & Colloids: The Bridge to Nanoscience*", Publisher: World Scientific (ISBN: 978-981-4299-82-4).
5	Assessment methods and criteria	Oral exam, short report on a research article related to a topic of the course, laboratory report.

Programme of "PROCESSI BIOLOGICI INDUSTRIALI" "INDUSTRIAL BIOPROCESSES"		
Number of ECTS credits: 9 (workload is 225 hours; 1 credit = 25 hours)		
I0311; COMPULSORY 2nd Cycle Degree in CHEMICAL ENGINEERING, 2nd year, 1st semester		
Teacher: Maria CANTARELLA		
1	Course objectives and Learning outcomes	The course has the objective of forming chemical engineering students with the fundamental knowledge of the main industrial bioprocesses, prevalently used in the food and pharmaceutical industries and in the environmental protection. At the end of this module the students will be able to analyze and understand the basic bioprocess limits and to suggest process solution and innovation in the fine chemical industry where the production of compounds of high and constant quality and with processes energetically advantageous and eco-friendly is required.
2	Course content and Learning outcomes (Dublin descriptors)	The knowledge of the main industrial bioprocesses is based on the study of the following topics: - Raw materials and pretreatment, - Microorganism metabolic pathways, microorganism culture, contamination, sterilization of the fermenter feed, ethanol fermentation and distillation with a critical discussion of the industrial process choices, - Protein purification strategy and techniques, - Bioprocesses for environmental protection, for each study case the applied kinetic mathematical models and possible innovative solutions are discussed, - Examples and discussions as well as presentation of study cases, are integral part of the programme for providing knowledge and understanding on the basic concepts of bioprocesses and capacity to be autonomous in the applications. On successful completion of this module, the student should o have profound knowledge and understanding of biological pathways, micro-organism metabolism, enzymatic catalysis, bioreactors, fermentation technology; o demonstrate skills in fermentation kinetics and ability to perform laboratory test for kinetic parameter evaluation; o be able to apply the acquired knowledge and understanding to evaluate process parameters using the mathematical models; o be able to explain different bioprocesses, by following a suitable scheme underlining the importance of the appropriate form of communication; o demonstrate capacity to work with a multidisciplinary team and to respect diversity; o be able to make autonomous choices and judgments through the discussion of the process flow-sheets and the comparison of the different adopted solutions; o be able to assess his work and adjust the methodology; o capacity to understand the innovative solutions based on recent research results and identify the need of lifelong learning to overcome process limits.
3	Prerequisites and learning activities	The student must know the fundamentals of biochemical engineering.
4	Teaching methods and language	Lectures, laboratory experiments, computer modelling, home work. Language: Italian or English

		Ref. Text books -J. Bailey & D. F. Ollis, *"Biochemical engineering fundamentals"*, Mc Graw Hill; -Murray Moo-young Ed *"Comprehensive Biotechnology";* -M.L. Shuler & F. Kargi, *"Bioprocess Engineering"*
5	Assessment methods and criteria	Oral exam.

Programme of "IMPIANTI CHIMICI II" **"*CHEMICAL PLANTS II*"**		
I2H014, COMPULSORY **2nd Cycle Degree in CHEMICAL ENGINEERING, 2nd year, 1st semester**		
Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)		
Teacher: Marina PRISCIANDARO		
1	Course objectives	The main aim of the course is to provide methodologies for the advanced sizing and operation of chemical plants and the design and analysis of the main complex chemical engineering process schemes, including their control and environmental impact. Objective of the course is also to provide all necessary instruments for the screening of processing alternatives and the redesign of chemical processes for pollution prevention and energy saving.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of this Module include: - Main advanced operations in chemical plants such as gas absorption with chemical reaction, multicomponent distillation (short cut and rigorous methods), non-ideal distillation (azeotropic, extractive), liquid-liquid extraction.The design and operation of these devices is emphasized; - Sizing of process equipment for complex process layouts; - Preliminary design of a large industrial project. At the end of this Module the students will o enhance their knowledge of fundamentals of mathematics and physics, applied to solve engineering problems; o improve their understanding of thermodynamics and fundamentals of momentum, heat and mass transfer; o be able to identify, formulate, and solve engineering problems; o be able to read and understand a complex process layout; o be able to size different process equipments; o be able to design a complex process scheme with relative flowsheet and control layout; o be able to carry out mass and energy balances on process scheme; o be able to evaluate energetic, economic and environmental performances of different processes.
3	Prerequisites and learning activities	Prerequisites: mathematics; chemistry; physics; thermodynamics.
4	Teaching methods and language	Lectures and exercises. Language: Italian / English Ref. Text books -Kern, *Process Heat Transfer*, McGraw-Hill -Robert E. Treybal, *Mass transfer operations*, McGraw-Hill -Coulson & Richardson, *Chemical engineering*, Pergamon Press -Perry, Green, *Perry's chemical engineer's handbook*, McGraw-Hill
5	Assessment methods and criteria	Oral examination; development and discussion of a technical report realized by students, whose topic is the industrial application of a chemical engineering unit operation.

Programme of "CHIMICA INDUSTRIALE" **"*INDUSTRIAL CHEMISTRY*"**
I1H005, COMPULSORY **2nd Cycle Degree in CHEMICAL ENGINEERING, 2nd year, 2nd semester**
Number of ECTS credits: 9 (workload is 225 hours; 1 credit = 25 hours)

Teachers: Katia GALLUCCI, Giuliana TAGLIERI		
1	Course objectives	Industrial Chemistry covers all fields of commercial production of chemicals and related products from natural raw materials and their derivatives, the exploitation of materials and energy production. The students will learn the bases of industrial chemical studies consisting of the evaluation of the processes as a whole: thermodynamics of involved reactions, analysis of kinetic and catalytic aspects, criteria of reactor selection and separation and purification methods including safety and environmental impact, elements of instrumental methods of analysis. These aspects are illustrated through proper training examination of some important examples of the chemical industry.
2	Course content and Learning outcomes (Dublin descriptors)	The list of topics are: - <u>First part:</u> The Italian and worldwide chemical industry. General criteria for chemical processes realization. Air separation. HCl synthesis from the elements. Absorption of corrosive gases. Synthesis gas: gasification of biomass and coal. H2 production. Bio-methane. Ammonia synthesis. Nitric acid. Sulfuric acid and sulfur. Phosphoric acid. NKP fertilizers. Sodium carbonate. Electrochemical processes. - <u>Second part:</u> Instrumental Analysis. General and selection criteria of measuring instrument. Theory of errors: overview. Introduction to the analytical methods. Spectroscopy. Characterization by X-radiation. Thermal analysis: DSC , TG, DTA . Measurements of porosity and pores distribution. Measurements of surface area. Light and electron microscopy. Gas and liquid Chromatography. On successful completion of this module, the student should: o know the chemical reactions and unit operations supporting the major processes of industrial chemistry; o understand the aspects of chemical processes (thermodynamics, kinetics, catalysis, reactor types, operating conditions, plant schemes, safety, environmental and economic aspects); o deeply know and understand important industrial processes for base chemicals; o be able to apply the basic chemical concepts to industrial processes; o have acquired calculation methods for equilibria, mass, and energy balances involved in chemical processes; o be able to assess criteria for developing sustainable chemical processes; o demonstrate skill to carry out properly laboratory projects on instrumental methods of analysis.
3	Prerequisites and learning activities	Students attending the course must have a knowledge of general chemistry, in particular the concepts of chemical equilibrium, mass action law, theory of acid-base and solubility equilibria, redox reactions, basic electrochemistry, chemical thermodynamics and kinetics, chemical reactor technologies. They are required to be able to write a report and process experimental data using appropriate mathematical tools and to perform literature search on English sources.
4	Teaching methods and language	Lectures, team work, laboratory projects Language: Italian/English Reference text books: -P. Basu, *Combustion and Gasification in Fluidized Beds*, CRC Press, 2006 - I. Pasquon, *Chimica industriale*, CittàStudi, 1993 -H.H. Willard, *Instrumental Methods of Analysis*, Wadsworth Publishing Company -R.W. Cahn, *Concise Encyclopedia of Materials Characterization*, Pergamon Press (ING) -Cozzi (SCI), *Analisi Chimica: Moderni Metodi Strumentali*, -Lecture notes provided by the teachers
5	Assessment methods and criteria	Oral exam, short report.

Programme of "CORROSIONE E PROTEZIONE DEI MATERIALI" ***"CORROSION AND MATERIALS PROTECTION"***
I0305, COMPULSORY **2^{nd} Cycle Degree in CHEMICAL ENGINEERING, 2^{nd} year, 2^{nd} semester**
Number of ECTS credits: 9 (workload is 225 hours; 1 credit = 25 hours)
Teacher: Carlo CANTALINI

1	Course objectives and learning autcomes	This Module aims to provide the students with basic and advanced knowledge and understanding of corrosion mechanisms of metal alloys, plastics and ceramic materials under different conditions, environments, both for civil and industrial applications. Students will be able to apply the acquired knowledge and understanding for materials selection, design and protection, and will acquire "problem solving skills" both in corrosion assessment and in addressing technical solutions, and capacity to report and communicate properly to top management and to the client.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: - Thermodinamic and kinetic aspects of electrochemical corrosion. - Low temperature corrosion and degradation of metal alloys: Galvanic, Pitting, Crevice, under deposit corrosion Impingment, Fretting, cavitation, Low temperature embrittlement, HE; Hydrogen Embrittlement, HIC; Hydrogen induced cracking e Hydrogen Blistering, Stress Corrosion Cracking, HSC Hydrogen Stress Cracking, SSC; Sulphide Stress Cracking in wet sour services, CSCC; Cloride Stress Corrosion Cracking, Alkaline stress corrosion cracking, Microbial Corrosion, Stray current corrosion. - High temperature corrosion of metal alloys: Spheroidization and graphitization of carbon stell, Temper embrittlement, creep embrittlement, Ferritic stainless steels 475°C embrittlement, Austenitic Stainless steels: Sigma Phase Embrittlement, Sensitization and weld decay Corrosion, Polythionic acid stress corrosion cracking (PASCC), High temperature Hydrogen attack, Sulfidization and sulfidic corrosion, Nitriding, Naphtenic acids Corrosion (NAC). - Methods and technologies to protect materials from corrosion. Materials selection and design to reduce corrosion under severe conditions. - Case studies in the chemical, petrolchemical and pharmaceutical industry. On successful completion of this module, the student should o have profound knowledge of corrosion mechanisms in different environments; o have knowledge and understanding of methods for predicting materials corrosion performances; o understand and explain materials, corrosion mechanisms, prevention and conservation of material; o demonstrate skill in material corrosion diagnosis and problem solving ability in materials protection issues; o demonstrate capacity for reporting and solution making.
3	Prerequisites and learning activities	The student must know the basic of "Materials Science and Technology" and "Chemistry"
4	Teaching methods and language	Lectures, case analysis, team work, exercises, reporting Language: Italian/english Ref. Text books -W.Callister, *Materials Science and engineering an introduction*, Wiley -H.H.Uhlig, *Corrosion and Corrosion Control*, Wiley -D. Hansen, *Materials selection for Hydrocarbon and chemical Plants*, CRC Press -ASM Handbook - Volume 13A: *Corrosion: Fundamentals, Testing, and Protection* -ASM Handbook -Volume 13B: *Corrosion: Materials* -ASM Handbook -Volume 13C: *Environments and Industries*
5	Assessment methods and criteria	Oral exam.

Programme of "IMPIANTI BIOCHIMICI INDUSTRIALI ED AMBIENTALI"
"DESIGN AND PROCESS ANALYSIS OF ENVIRONMENTAL AND BIOCHEMICAL PROCESSES"

I0301, ELECTIVE from a compulsory list of three possible teaching activities
2nd Cycle Degree in CHEMICAL ENGINEERING, 2nd year, 1st semester

Number of ECTS credits: 9 (workload is 225 hours of teaching; 1 credit = 25 hours)

Teacher: Prof. Francesco VEGLIO'

1	Course objectives	The main objective of the course is to give the main information and tools on the design of biochemical and environmental processes with particular attention to biotechnological applications, municipal and industrial wastewater treatments and waste recycling. General criteria of design of bioreactors, mixing, up-stream and downstream technologies are also described, providing some practical and existing engineering examples, where the general approach to carry out process analysis and its technical-economical feasibility are illustrated.

		In this manner the students should be able to design biochemical and environmental processes until to the estimation of the technical and economical feasibility studies. This module is linked to other teaching modules of the second year because it gives some practical instruments to design chemical and biochemical processes and at the same time it gives some useful and practical skills often required in industrial practical experience.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: - Biochemical process as a stoichiometry. Kinetic models of microbial growth. - Bioreactors configuration: batch, continuous and semi-continuous bioreactors. - Bioreactors with partial recirculation of biomass, bioreactors in series, membrane bioreactors. Stability of bioreactors. Oxygen mass transfer and mixing. - Up-stream and downstream processes: cell rupture, filtration, centrifugation, sedimentation, membrane processes (micro and ultra filtration, nano filtration and reverse osmosis), sterilization, liquid-liquid extraction with and without chemical reaction. process analysis and use of commercial software for technical and economical feasibility studies. On successful completion of this module, the student should - have profound knowledge of bio reactors and downstream design procedures; - have knowledge and understanding of theoretical and practical principles of process analysis; - understand and explain the meaning of complex and integrated processes in the ambit of biochemical and environmental industrial sectors; - understand the fundamental concepts and criteria for the design of several equipments and their use within several industrial applications; - demonstrate skill in the use of some commercial software to carry out technical and economical feasibility studies; - demonstrate capacity for reading and understanding other texts on related topics.
3	Prerequisites and learning activities	Prerequisites: applied chemistry, thermodynamics, mass and heat transfer operations; The student must know the notions of design of chemical and biochemical reactors with the related downstream unit operations.
4	Teaching methods and language	Lectures and exercises. Language: Italian / English Ref. Text books -James Edwin Bailey, David F. Ollis, *Biochemical engineering fundamentals*, Mc Graw-Hill, 1986 -Shuichi Aiba, Arthur Earl Humphrey, Nancy F. Millis, *Biochemical engineering,* Academic Press, 1973 -Some didactic materials and scientific papers published by the teacher
5	Assessment methods and criteria	Written and oral examination, realization and discussion of a technical report realized by students before the final examination

Programme of "SCIENZA E TECNOLOGIA DEI MATERIALI II" ***"SCIENCE AND TECHNOLOGY OF MATERIALS II"***		
I0593, ELECTIVE from a compulsory list of three possible teaching activities **2nd Cycle Degree in CHEMICAL ENGINEERING, 2nd year, 1st semester**		
Number of ECTS credits: 9 (workload is 225 hours; 1 credit = 25 hours)		
Teacher: Mario PELINO		
1	Course objectives and Learning outcomes	The course aims to provide students with the advanced notions of chemistry and solid state physics applied to the study of materials science and technologies as well as employment of materials in different branches of application. Chemical, thermal, and mechanical properties are related to structure, composition, morphology of phases. The properties and applications of ferrous and non-ferrous (aluminium, nickel, copper) of advanced ceramics and glass-ceramics, polymers is detailed. Typical practical applications are presented in the second part of the course. On successful completion of this module, the student should understand the fundamental concepts of solid state chemistry and physics, the properties of engineering materials, the production technology and applications, the basic concepts of materials recycling .
2	Dublin descriptors	Topics of the module include:

		- Elements of general chemistry, structure of atoms and molecules. Atomic bond of solids. Covalent and ionic solids metallic. - The crystal structures. The Miller indices. Plans and directions at maximum density. Solidification. Defects in crystals . X-ray diffraction and Bragg's law . The solids under stress : the movement of atoms in the crystal lattice . Fick's laws of diffusion . Diffusion in metals, in the oxides in the glass. - Mechanical tests on materials: strength, fatigue, toughness, hardness, creep. - Thermodynamics of solid solutions. The Gibbs phase rule. Partial and complete miscibility. Immiscibility. Characteristic points in the phase diagrams. Diagrams of Fe-C , Al- Cu , Cu -Zn , Cu -Sn . Phase diagrams of silica - alumina. Ternary diagrams . The solidification process. - The metal alloys, ferrous: Curves Bain , the isotherms and an- isotherm quenching and tempering , annealing, normalising. The steels, carbon steels. Austenitic stainless steels, ferritic and martensitic steels. Duplex. Solution strengthening. Steels for cryogenic and high temperatures application. The special alloys. - The non ferrous alloys: aluminium alloy hardening and work hardening. Alloys by extrusion and reclamation. Anodizing. Alloys of copper. Brass, bronze, cupro-nickel. Nickel alloys: properties, technology and application. - The ceramics: Crystalline structures, the structure of silicates, defects in ceramic materials, brittle fracture, stress-strain behaviour, scientific aspects of sintering; fabrication techniques. Traditional and advanced ceramics, thermal and electrical properties. Techniques for inducing toughening in ceramics . Application of advanced ceramics. - Properties of glasses, lattice formers and modifiers, the glass transition temperatures, temperature vs viscosity curves. - Glass - ceramics: nucleation and crystallisation; properties and applications . - Polymers: Polymerization reactions : thermoplastic polymers , thermosetting . The vulcanization process of the elastomers. - Basic notions of soldering metals; mechanical and chemical properties modification due to soldering. - Basic notions of materials recycling.
3	Prerequisites and learning activities	Advanced notions of General Chemistry, Physics and Mathematics
4	Teaching methods and language	Lectures and exercises. Language: Italian / English Ref. Text books -W.F. Smith - *Scienza e Tecnologia dei Materiali* - McGraw-Hill -W. Nicodemi. *Metallurgia* - Ed. Masson -W.D. Callister - *Materials science and Engineering* - John Wiley and Sons, Inc.
5	Assessment methods	Oral exam.