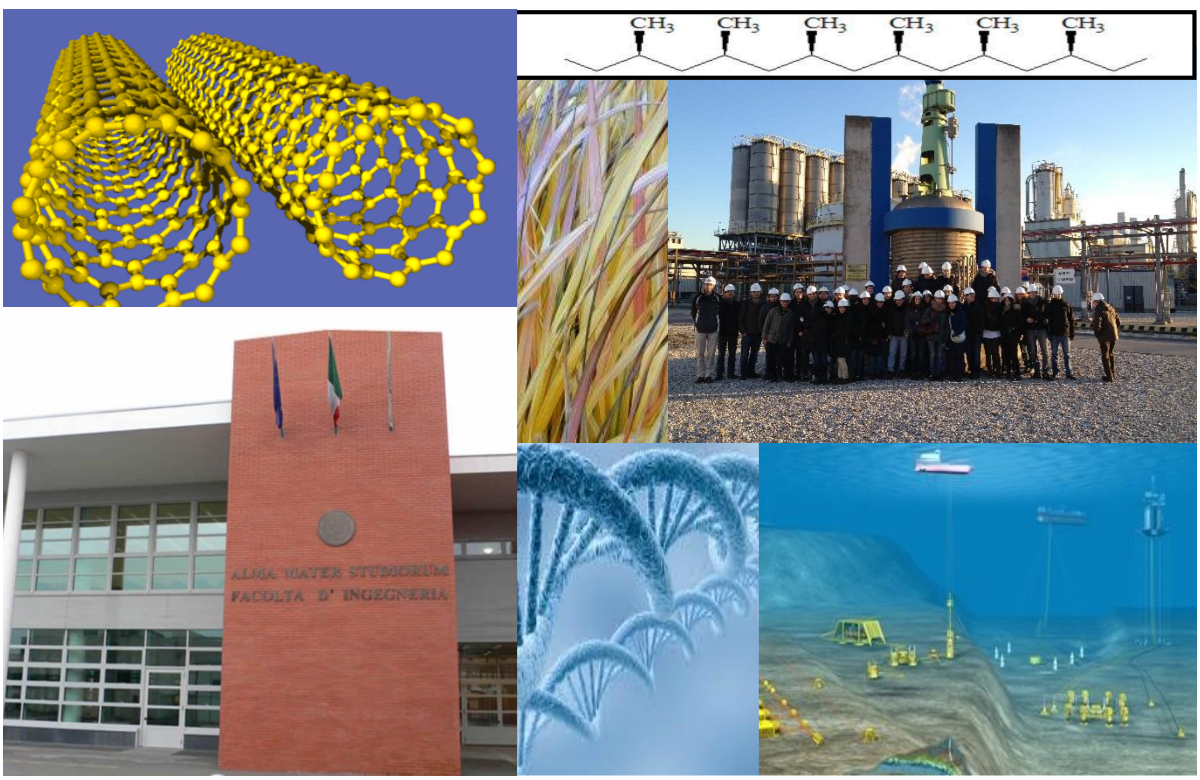
ALMA MATER STUDIORUM
UNIVERSITA' DI BOLOGNA

Second Cycle Degree / Two Year Master

CHEMICAL & PROCESS ENGINEERING

STEM International Curriculum
Sustainable Technologies and biotechnologies for Energy and Materials



School of Engineering and Architecture – Terracini Campus
via Terracini 28, 40131 Bologna, Italy

Second Cycle Degree / Two Year Master

CHEMICAL & PROCESS ENGINEERING

Curriculum STEM – Sustainable Technologies and biotechnologies for Energy and Materials

Presentation

A Masters degree in chemical engineering is a key to professional success in several modern and innovative industrial sectors. Smart materials, sustainable processes for energy production, industrial biotechnologies, and advanced pharmaceutical applications are only some of the examples of sectors where the expertise of chemical engineers is sought and highly rewarded.

The conventional world-players, such as the chemical and Oil&Gas industry, are undergoing increasing innovation and internationalization, thus requiring global competences and higher qualifications from the chemical engineers recruited.

The STEM (Sustainable Technologies and biotechnologies for Energy and Materials) curriculum of the Masters in Chemical and Process Engineering was built to meet these needs.

The program is a two-year Master "second cycle degree" entirely taught in English and officially recognized under the "Bologna Process". The program requires the students to obtain 120 ECTS, has a two years in duration and is divided into four terms. In the first year, courses deepen the understanding of fundamental concepts: advanced thermodynamics and transport phenomena, introduction to basic design, and introduction to industrial safety. In the second year, both compulsory and elective courses are offered on specialized topics, such as materials, industrial biotechnologies, energy, oil&gas technologies, off-shore engineering.

At the end of the program, a degree titled "Master in Chemical and Process Engineering" (Laurea Magistrale in Ingegneria Chimica e di Processo, Classe LM-22) is awarded and is valid under Italian law.

Graduates of the program will have the training to go on to work in numerous fields, including the conventional chemical and process industry (petrochemical, specialty chemicals, pharmaceutical), the wide-spread energy industrial sectors (up-stream and down-stream Oil&Gas, energy generation, green energy production), and many other specialized sectors (material production, food technologies, industrial biotechnologies, etc.). Completion of the STEM Masters degree can also lead to entering PhD. level studies.

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Curriculum **STEM** – Sustainable Technologies and biotechnologies for Energy and Materials

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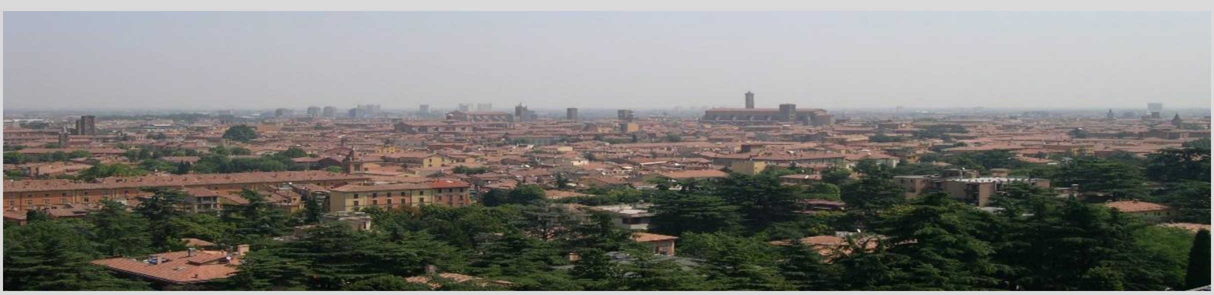

UNIVERSITY OF BOLOGNA

The institution that we today call the University of Bologna was the first university in the western world, taking shape in Bologna at the end of the eleventh century. In line with their strong tradition, the University of Bologna is now one of the most important and best reputed of the Italian universities.

Bologna is characterized by the largest Italian medieval historical city centre, and is very friendly to the 80.000 students that constitute 16% of its population.

Second Cycle Degree / Two Year Master

CHEMICAL & PROCESS ENGINEERING

Curriculum **STEM** – Sustainable Technologies and biotechnologies for Energy and Materials

COURSE STRUCTURE

The STEM (Sustainable Technologies and biotechnologies for Energy and Materials) curriculum is a two year program (four terms) entirely taught in English and requires students to obtain 120 ECTS.

In the first year, the compulsory courses (a total of 42 ECTS) deepen the understanding of fundamental concepts of Chemical engineering, such as: advanced thermodynamics and transport phenomena, introduction to basic design, and introduction to industrial safety. Further 12 ECTS in the first year are dedicated to electives and laboratories.

In the second year, compulsory courses (36 ECTS) and electives (12 ECTS) focus on specialized topics, such as materials, energy and environmental processes, and industrial biotechnologies. Two alternatives are possible: in the Bologna Campus, courses are tailorized to deepen knowledge and skills on **biotechnologies and materials**. In the Ravenna Campus, courses on **off-shore engineering and up-stream Oil&Gas technologies** are offered. In both Campuses, second year electives (12 ECTS) can be selected from several topics, ranging from structural engineering to environmental applications and industrial safety.

This program also requires each student to complete a research project (18 ECTS), before becoming eligible to graduate.

It may be possible for students to spend periods of study abroad, in particular during the second term of the second year and for the Masters research project. This includes the opportunity for students to carry out part of their Masters research project in the framework of the collaborative research project between the University of Bologna and private companies or various international research institutes.

At the end of the program, a degree titled 'Masters in Chemical an Process Engineering' (Laurea Magistrale in Ingegneria Chimica e di Processo, Classe LM-22) is awarded and is valid under Italian law.

A “Dual Degree” program is currently being offered with Columbia University - New York. Students accessing this program are required to spend the second year at CU NY. After completing the program, the students will be awarded a “Masters in Chemical Engineering” by both universities.

Second Cycle Degree / Two Year Master

Chemical & Process Engineering

Curriculum **STEM** – Sustainable Technologies and biotechnologies for Energy and Materials

CAREER OPPORTUNITIES from the STEM program

Successful completion of the STEM Masters degree allows graduates to pursue their professional career or continue their academic career.

Among the more important professional sectors addressed by Master studies in Chemical Engineering are:

The conventional Chemical and Process Industry, and in particular the petrochemical, polymers, specialty chemicals, and pharmaceutical sectors: this industry is characterized by increasing globalization and is steadily recruiting qualified chemical engineers throughout Europe.

The Energy sector: Oil&Gas, both up-stream and down-stream, strongly requires qualified chemical engineers for design and operation in a framework of growing complexity and innovation towards increasing sustainability and environmental compatibility. The Off-Shore Engineering and Oil&Gas Technologies option in year 2 allows obtaining specific skills to pursue a professional career in this sector.

The Material sector, with its development towards nanomaterials and smart materials requires qualified chemical engineers to answer the demand for innovation and life-cycle sustainability.

The Biotechnology sector, with its evolution towards large-scale production, has a growing requirement of qualified chemical engineers able to support the industrialization of biotechnological processes and their operations.

The Environmental sector, with the growing development of processes for the recovery of wastes, the valorization of biomass and the implementation of safe and sustainable technologies, needs qualified chemical engineers as a necessary support to its large-scale operations.

For those who want to further study Chemical Engineering in an academic context, graduates of this program are eligible to enter into PhD. studies at the University of Bologna.

Second Cycle Degree / Two Year Master

CHEMICAL & PROCESS ENGINEERING

Curriculum STEM – Sustainable Technologies and biotechnologies for Energy and Materials

ADMISSION REQUIREMENTS, ENROLMENT, TERMS and CONTACT DETAILS

A bachelor in Chemical Engineering is required for admission. Applicants holding a bachelor in other engineering disciplines or in industrial chemistry may be considered for admission, depending on their curricula.

Applicants with a bachelor degree from a non-EU country or one that is different from chemical engineering are requested to submit their application to the admission committee prior to applying online to the university, in order to verify the suitability of the undergraduate training to access this Masters program. A specific call is opened for this purpose between February and June each year.

Enrolment is then possible each year from August to December. Students who are not EU citizens should also apply for a study permit and for pre-enrolment from the Italian embassy in their country (period is usually January to June each year)

Full details on admission procedures may be found at the following website:

http://corsi.unibo.it/2cycle/ChemicalProcessEngineering-STEM/Pages/default.aspx

Lessons, entirely in English, begin each year around mid-September. First term is from mid-September to mid-December. Second term is from mid-February to mid-June. Full-time attendance is mandatory.

Bologna is a public university; tuition fees are set each year by the academic authorities. Fee waivers and other grants may be available.

For further information please contact us and visit our website:

http://corsi.unibo.it/2cycle/ChemicalProcessEngineering-STEM/Pages/default.aspx

Contacts:

dicam.didattica@unibo.it

Support to International Courses – DICAM

Via Terracini 28, 40131 Bologna (BO)

Tel +39 051 2093358

Course Diagram

Academic Year 2016/2017 - Second Cycle Degree - Chemical and Process Engineering – STEM Curriculum

First year	Hours	Term	ECTS
1) Mandatory courses (42 ECTS)			
FLUID MECHANICS AND TRANSPORT PHENOMENA M	72	I	9
MATERIALS CHEMISTRY M	48	I	6
NUMERICAL METHODS M	72	I	6
THERMODYNAMICS OF ENERGY AND MATERIALS M	48	I	6
INDUSTRIAL SAFETY M	48	II	6
INTRODUCTION TO BASIC DESIGN M	48	II	9
2) Select one of the two alternatives (6 ECTS)			
INTERNSHIP FOR MASTER THESIS PREPARATION	0	II	6
RESEARCH PROJECT A	60	II	6
3) Elective courses (choose 12 ECTS among the following courses)			
ENGLISH LANGUAGE SKILLS	24	I	3
ITALIAN LANGUAGE AND CULTURE	24	I	3
LABORATORY OF ADVANCED PROCESS SIMULATION	24	I	3
LABORATORY OF CHEMICAL AND BIOCHEMICAL REACTORS M	24	I	3
LABORATORY OF INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGIES	24	I	3
LABORATORY OF THERMODYNAMIC SIMULATION	24	I	3
TRANSPORT PHENOMENA LABORATORY M	24	I	3
LABORATORY OF BIOMEDICAL MATERIALS AND TECHNOLOGIES	24	II	3
LABORATORY OF INDUSTRIAL SAFETY M	24	II	3
LABORATORY OF MATERIALS CHARACTERIZATION M	24	II	3
LABORATORY OF MOLECULAR DESIGN AND MATERIALS SIMULATION	24	II	3
LABORATORY OF PHOTOCATALYSIS	24	II	3

Second Year	Hours	ECTS
1) Mandatory courses (6 ECTS)		
RESEARCH PROJECT B	0	12
2) Elective courses (48 ECTS)		
2.1) Option 1 – Bologna Campus: Materials & Biotechnologies (48 ECTS)		
2.1.1) Mandatory courses (36 ECTS)		
BIOREACTORS AND DOWNSTREAM PROCESSES M	72	9
INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGY M	72	9
POLYMER SCIENCE, TECHNOLOGY AND RECYCLING M	48	6
PROCESS ANALYSIS FOR ENERGY AND ENVIRONMENT M	48	6
TECHNOLOGY AND SUSTAINABILITY OF COMPOSITE MATERIALS M	48	6
2.1.2) Courses freely chosen by the student (choose 12 ECTS among the following courses)		
COMPUTATIONAL MECHANICS M	48	6
ENGLISH LANGUAGE SKILLS	24	3
INDUSTRIAL ECOLOGY M	72	9
ITALIAN LANGUAGE AND CULTURE	24	3
LABORATORY OF ADVANCED PROCESS SIMULATION	24	3
LABORATORY OF BIOMEDICAL MATERIALS AND TECHNOLOGIES	24	3
LABORATORY OF INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGIES	24	3
LABORATORY OF INDUSTRIAL SAFETY M	24	3
LABORATORY OF MATERIALS CHARACTERIZATION M	24	3
LABORATORY OF MOLECULAR DESIGN AND MATERIALS SIMULATION	24	3
LABORATORY OF PHOTOCATALYSIS	24	3
LABORATORY OF THERMODYNAMIC SIMULATION	24	3
MATERIALS CHARACTERIZATION M	24	3
PETROLEUM GEOSYSTEM M	48	6
SOLID STATE ELECTRONICS M	60	6
SOLID STATE PHYSICAL CHEMISTRY M	60	6
TRANSPORT PHENOMENA LABORATORY M	24	3
2.2) Option 2 – Ravenna Campus: Offshore engineering (48 ECTS)		
2.2.1) Mandatory courses (36 ECTS)		
BIOREMEDIATION AND EXPLOITATION OF MARINE BIORESOURCES	48	6
CORROSION AND PROTECTION OF METALLIC OFFSHORE STRUCTURES	48	6
EXPLOITATION OF OFFSHORE O&G RESOURCES	96	12
OFFSHORE ENGINEERING AND HSE MANAGEMENT	72	9
TURBOMACHINES AND POWER GENERATION FOR OFF-SHORE APPLICATIONS	24	3
2.2.2) Courses freely chosen by the student (choose 12 ECTS among the following courses)		
DESIGN OF OFFSHORE STRUCTURES AND FOUNDATIONS	72	9
INTERNSHIP	150	6
LABORATORY OF OFFSHORE OPERATIONS	48	6
MODELLING OF OFFSHORE STRUCTURES	48	6
MONITORING AND POSITIONING IN OFF-SHORE ENGINEERING	48	6
OCEAN AND COASTAL ENGINEERING	72	9
PROJECT MANAGEMENT IN OFFSHORE ACTIVITIES	48	6

COURSE CONTENTS

In the following, learning outcomes and course contents are summarized for all required and elective courses available to STEM students. Courses are listed in alphabetic order.

BIOREACTORS AND DOWNSTREAM PROCESSES M

(Prof. Cristiana Boi)

The course aim is to provide students with a basic and advanced techniques for reactor and bioreactors analysis and design, as well as knowledge of downstream and purification processes.

Course Contents:

Elements of reaction kinetics: reaction rate, order of reaction, catalysis, enzymes, Kinetics of biological interest: Monod kinetic model, structured and segregated models.

Mass and energy balances for ideal reactors: batch, CSTR and PFR.

System of expression: bacterial cells, yeast and mammalian cells.

Operating modes and performance analysis of bioreactor: continuous systems, batch and semi-continuous (fed-batch). Conduction of bioreactors and problems of conversion.

Air-lift bioreactors and agitated bioreactors with immobilized biomass: configurations, features and operating modes. Biological waste water treatment: activated sludge and supported biomass systems (biological filters, RBC), membrane bioreactors (MBR).

Principles of separation processes, choice of the appropriate unit operation for a given separation. Cell lysis: osmotic, chemical and mechanical methods.

Sedimentation: equation of motion, equilibrium sedimentation. Centrifugation: description and use of different centrifuges. Sigma analysis.

Filtration: conventional and cross flow filtration. Filter media and equipment.

Flocculation: theory of electrical double layer, DLVO theory, flocculant agents.

Protein precipitation: protein solubility (salting in and salting out), precipitate formation phenomena, design of precipitation systems.

Membrane separation processes: classification based on the driving force, description and use of different membrane processes in biotechnology. Membrane modules: plate and frame, hollow fiber, tubular. Concentration polarization: film theory model. Microfiltration, ultrafiltration and diafiltration. Membrane fouling. Sterile filtration and filtration for virus removal.

Liquid/liquid extraction: extraction with solvent, extraction in aqueous phase. Stage calculation. Scale-up and design of extractors.

Adsorption: fundamental principles, equilibrium isotherms.

Chromatography: process description, chromatographic techniques. Chromatography column dynamics: plate theory, column efficiency, Van Deemter equation, theory of adsorption chromatography.

Crystallization: crystal formation and their characteristics. Phase diagrams- Protein crystallization. Crystallizers.

Monoclonal antibody production: process analysis and economic evaluation. Polishing steps: AEX, CEX, HIC and mixed mode chromatography.

Examples of other biotechnological processes

BIOREMEDIATION AND EXPLOITATION OF MARINE BIORESOURCES M

(Prof. Giulio Zanaroli)

The course will provide students with the knowledge of biochemistry, microbiology and bioprocessing required for the sustainable remediation of impacted marine ecosystems (surface and subsurface water and sediments) and the industrial exploitation of marine biodiversity and bioresources.

Course contents:

Biodiversity of the marine microorganisms

Cellular organization, physiology, nutritional requirements and main features of marine bacteria, fungi and algae. Microbial metabolisms in the marine environment: photosynthesis; aerobic respiration, anaerobic respiration (nitrate-reduction, Fe(III)-reduction, sulfate-reduction, acetogenesis, methanogenensis), and fermentation of organic compounds; oxidation of inorganic compounds such as ammonium, sulfur, sulfide, iron(II). Microbial ecology of the marine (extreme) environment(s) and its monitoring.

Bioremediation of impacted marine ecosystems

Common pollutants of the marine environment: classification, source, fate and environment impact. Marine microorganisms mainly involved in the biotransformation/biodegradation of organic pollutants and biochemical-molecular mechanisms responsible for their adaptation to the polluted environment. Biodegradation of oil hydrocarbons and halogenated xenobiotics in aerobic, surface and subsurface seawater and in anaerobic sediments. Strategies for the enhancement of aerobic and anaerobic bioremediation processes in the surface and subsurface seawater and in marine sediments (pollutant mobilization and bioavailability enhancement, biostimulation with nutrients (N, P) or electron donors, bioaugmentation, bioelectrochemical approaches). Management and main strategies for the ex-situ and in-situ (bio)remediation of contaminated sediments. -Valorization of remediated or non contaminated dredged sediments.

Exploitation of marine bioresources

Bioactive compounds for pharmaceutical, nutraceutical, cosmetic, agrochemical applications from marine bacteria, fungi, micro- and macroalgae and cyanobacteria; functional food ingredients from marine microbes, macroalgae and fish; pigments and colorants for the food and cosmetic industry from marine filamentous fungi; new enzymes from marine extremophiles; the integrated production of chemicals, materials and fuels (biorefinery) from marine biomass and fish processing byproducts and waste; Biofuels from the exploitation of marine (micro)algae (biodiesel, algal biomass for combustion; biogas via anaerobic digestion of the biomass; biohydrogen; bioethanol via fermentation of carbohydrates derived from algae).

COMPUTATIONAL MECHANICS M

(Prof. Francesco Tornabene)

The course is an introduction to Computational Mechanics of Solids and Structures. The goal of the course is to provide the students with the fundamental concepts and operating tools to solve current structural problems using computer technology.

Course Contents:

The course provides an overview of the Finite Element formulations and methods (FEM), addressed to structural analysis.

Topics cover also relevant computational aspects, allowing students to understand how both linear and nonlinear mechanical phenomena can be faced. Topics also cover relevant formulation and computational aspects of modeling laminated structures, either in static deformations or free vibrations. Various shear deformation theories will be explained in detail. MATLAB codes will be given to students and examples will be proposed.

The lectures consist of two short courses of 30 hours each, based on linear elasticity.

The courses include both lessons and laboratory activities regarding the following topics:

1) Short introduction to MATLAB

2) Discrete Systems

3) Analysis of Bars

4) Analysis of 2D Trusses

5) Trusses in 3D Space

6) Bernoulli Beams

7) 2D Frames

8) Analysis of 3D Frames

9) Analysis of Grids

10) Analysis of Timoshenko Beams

11) Plane Stress

12) Analysis of Mindlin Plates

13) Laminated Plates

CORROSION AND PROTECTION OF METALLIC OFF-SHORE STRUCTURES M

(Prof. Maria Chiara Bignozzi)

Morphology of corrosive phenomena in marine environment, rate and penetration of corrosive attacks. Electrochemical corrosion mechanisms. Thermodynamics: Nerst equation, corrosion tendency and electrode potentials, Pourbaix diagrams. Kinetics: polarization and corrosion rate, causes of polarization. Passivation theory. Localized corrosion: selective corrosion, pitting, stainless steel sensitization, etc. Effect of stress and environment: stress corrosion cracking, corrosion fatigue, hydrogen cracking, etc. Thermal, chemical, mechanical treatments of metal surfaces and protection methods: metallic, inorganic and organic coatings. Anodic and cathodic protection. High-temperature resistant materials. Definition of selection criteria for metals suitable for marine environment and off-shore applications.

DESIGN OF OFFSHORE STRUCTURES AND FOUNDATIONS

(Prof. Laura Govoni, Prof. Claudio Mazzotti)

The aim of the course is to provide for the basic and some advanced elements for design of offshore structures. After an extensive illustration of requirements and protocols for certification of steel for construction, the elements of design of steel structures will be given, including strength requirements, instability verification, design of connections (bolted and welded), with particular emphasis to those typical of off shore structures. Design criteria on more complex steel elements (tanks, pipes, plates, shell, etc) will be also given. Criteria for life extension of existing off shore platforms will be also given. Then, typologies of foundations for off shore structures will be illustrated, together with the design criteria for different soil and loading conditions.

Content

Introduction to structural design for offshore structures: Overview on the main design codes (ISO, API, Norsok); Materials: steel for offshore structures, concrete. Limit state design fundamentals. Loads.

Design of fixed steel structures: Strength requirements; Stability of structural members; Bolted connections; Welded connections.

Seismic design of fixed steel structures: Seismic hazard and design spectra; Ductility requirements and seismic design.

Life extension of existing platforms: Fatigue analysis; Stress ranges and hot-spots; Residual fatigue life.

Design of steel plates and shells: Flexural behaviour of plates; Flexural behaviour of circular cylinders; Design criteria for plates and shells.

Introduction to geotechnical site investigations: Investigation platforms. Drilling and coring systems. CPT, T-bar and ball penetrometers. Sampling equipment. Data interpretation.

Piled foundations: Offshore applications of piled foundations. Basis of design of offshore piled foundations. Drilled and grouted piles. Piles drivability. Axial capacity e axial response of piled foundations. Lateral capacity and lateral response of piled foundations. Axial and lateral cyclic response of piled foundations. Piled foundations for offshore wind turbine applications.

Shallow foundations: Offshore applications of shallow foundations. Types of offshore foundations: gravity bases, bucket foundations. Basis of design of offshore shallow foundations. Installation issues offshore of shallow foundations: suction caissons. Capacity under static general loading conditions of shallow foundations. Cyclic response of offshore shallow foundations. Macro-element modelling of shallow foundations in static and cyclic conditions. Shallow foundations for offshore wind turbine applications.

Overview of main anchoring systems: Overview of anchor types: surface gravity anchors, anchor piles, suction caissons anchors and drag anchors. Basis of design of main anchoring systems.

EXPLOITATION OF OFF-SHORE OIL&GAS RESOURCES M

(Prof. Paolo Macini, Prof. Alessandro Tugnoli, Ing. Giambattista De Ghetto)

The aim of the course is to introduce the student to the processes and technologies for the exploitation of off-shore Oil&Gas resources. The student will gain knowledge on the exploitation principles of off-shore reservoirs and on sub-sea, top-side and floating production technologies.

Course Contents:

Petroleum Engineering

Overview of the Oil & Gas industry and basics of petroleum economics. Evaluation of oil and gas reserves: definition and classification of reserves. Italian legislation concerning oil and gas leases. Hydrocarbon reservoirs: conditions for the existence of an oil or gas reservoirs, sedimentology, generation and migration of hydrocarbons; hydrocarbon traps. Temperature and pressure in petroleum systems. Physical properties of reservoir fluids. Reservoir distribution of petroleum fluids. Thermodynamic classification of hydrocarbon reservoirs.

Oil & Gas reservoir rock properties: core logs, porosity, compressibility, wettability, basic concepts of capillary pressure curves, porosity, absolute and relative permeability.

Formation evaluation and well logging: wireline logging and logging while drilling. Fundamentals of Reservoir Engineering. Crude oil and natural gas reserves estimation.

Rotary drilling and oil well drilling engineering. Configuration of rotary drilling rigs (offshore and onshore) for the construction of deep wells for the production of underground fluids (water, natural gas, crude oil, geothermal fluids). Drill bits and drill string. Drilling fluids, casing and cement operations. Wellhead design, safety equipment and BOP (Blow Out Preventers) configuration. Directional drilling: borehole profiles, well path directional control technologies, directional surveying, well path calculation methods.

Offshore oil well drilling. Special offshore drilling vessels: drilling barges, jack-up units, semi-submersible units, drilling ships. Mooring and dynamic positioning systems. Drilling marine riser, subsea wellheads and BOPs. Motion compensation systems.

Production technologies

Introduction to Oil&Gas exploitation technologies: structure of the petroleum industry, oil&gas production, main up-stream and mid-stream processes, relevant design standards and codes. Topside upstream technologies: upstream gas processing, upstream oil processing, wellheads, separation, pumping, compression, gas treatments, auxiliary units, pipeline transportation, hydrate inhibition. Subsea upstream technologies: introduction to subsea technologies, system architecture, wellheads, flow-lines, separation, pumping/compression, gas treatments, auxiliary units, sub-sea installation and maintenance. LNG technologies for off-shore applications: the LNG chain, LNG transportation, types of LNG terminals, off shore LNG processing, offloading, storage tanks, vaporizers, quality correction, boil-off gas management. Basis of design for off-shore technologies: design of heat exchange equipment, separation equipment, pumps/compressors, and utilities.

FLUID MECHANICS AND TRANSPORT PHENOMENA M

(Prof. Maria Grazia De Angelis, Prof. Giulio Cesare Sarti)

The course mainly addresses the continuum-level analyses of non-equilibrium processes in fluids (e.g., fluid flow under applied force, energy or mass transfer in flowing fluids). Continuum-level balance laws for mass, energy and momentum are derived. These provide the basis for the fluid mechanical and heat or mass transfer analyses in engineering. The need for material-specific “constitutive laws” for the “conductive” fluxes of mass, energy and momentum is demonstrated. These are developed from continuum and thermodynamic principles with reference to key experimental tests. Applications of the continuum theory are discussed to define important classes of problems, to demonstrate analytical methods, and to derive quantities usually sought in engineering analyses. Specific topics:

Course Contents:

Continuum View; Kinematics; Mass & Momentum Balances; Simple Fluid Constitutive Laws; Non-Newtonian Fluids; 1D and Nearly 1D Laminar Flows of Incompressible Newtonian Fluids; (scaling and dimensional analysis of the NS equations, significance of the Reynold's number (Re), laminar vs turbulent flow; fully developed, steady 1D flows in cylindrical conduits; Hamel Flow; lubrication flows, order of magnitude analysis for lubrication flows, analysis of the boogie board). 2D Flows (general notion of the stream function for incompressible fluids; stream functions for plane and axisymmetric flows; NS eqns in terms of the stream function). Low Re Flows (low Re approximation, Stokes' equation; Hamel flow at low Re; a 2D flow: Stokes flow past a sphere, the sedimentation process; problems with Stokes' equation). High Re Flows (high Re approximation, Euler's equation,; Bernoulli's Eqn,; Hamel flow at high Re; problems with Euler's equation). Energy and Entropy Balance (developing a continuum field theory for non-isothermal systems, minimal local description; energy concepts, energy content, energy transduction (work and heat); energy balance via RTT, partial reduction to "temperature only" form; need for additional constitutive laws; entropy balance and the second law, thermodynamic constraints on constitutive laws; linearized constitutive laws, Fourier's law, the Navier-Stokes-Fourier (NSF) fluid). Heat Conduction (1D steady state heat conduction and generation in solids; 1D transient heat conduction problems in solids; heat transfer fin effectiveness). Forced Convection HT (forced vs free convection; dimensional analysis of nonisothermal incompressible NSF fluid dynamics, Peclet number (Pe); heat transfer coefficients and the Nusselt number (Nu); a 1D forced convection energy transport process; Graetz and Leveque forced convection heat transfer problems). Kinematics and Constitutive Equations for Mass Transport in Binary and Multicomponent Systems (component velocities and diffusive fluxes in multicomponent systems; Fick's constitutive equation for diffusive flux in binary mixtures; Stefan-Maxwell relations for diffusive fluxes in multicomponent systems). Diffusion Dominated Problems in Binary Systems (1D steady state mass diffusion and generation in solids and fluid at rest; 1D transient mass diffusion problems for sorption and permeation processes; catalyst effectiveness factor). Mass Transfer with Fluid Flow (film theory for mass transfer coefficients, surface renewal theory for mass transfer coefficients, effect of homogeneous reaction on mass transfer coefficients in fluids)

INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGIES M

(Prof. Fabio Fava)

The aim of the course is to provide the fundamentals of applied biochemistry and microbiology required to understand the role of biological agents in the main biotechnological processes of industrial and environmental relevance.

Course Contents:

1) Potential of Industrial and Environmental Biotechnologies in the chemical, pharmaceutical, food, textile and biofuel industries and in bioremediation.

2) Enzymes and microorganisms of industrial and environmental interest and their main current applications. Use of microbial cultures in batch, fed- batch and continuous reactors and kinetics description of the processes.

3) Chemical compounds released into the environment: biogenic and xenobiotic compounds. Biotransformation of biodegradable compounds: anabolic and catabolic pathways, Gibbs free energy, cell bioenergetics. Metabolism of organic biogenic compounds. Aerobic metabolism: the two glycolysis pathways, the Krebs cycle and the oxidative phosphorylation. Examples of environmental relevant microorganisms living by respiring aerobically biogenic organic compounds.

4) Anaerobic metabolism: biochemistry of the nitrate-reduction, Fe(III)-reduction, sulphate-reduction, HCO_3^--reduction and main features of microorganisms using such anaerobic respiration routes. Fermentation of carbohydrates and proteins occurring in the environment (alcoholic fermentation, lactic fermentation and the other fermentations addressed to produce solvents and organic acids of industrial interest) and features of the main microorganisms responsible for them. Fermentation and anaerobic respiration processes associated to the anaerobic digestion of organic matter (biomethanization).

5) Metabolism of inorganic compounds: nitrification, S° or $S^=$ -oxidation, Fe(II) oxidation and industrial microbial leaching CO_2 autotrophic fixation. Sources and fate of the main organic and inorganic xenobiotic compounds in contaminated soils, sediments and waters.

6) Microorganisms mainly involved in their biotransformation and detoxification and biochemical-molecular mechanisms responsible for their adaptation to the polluted environment. Biodegradation pathways for aliphatic and aromatic hydrocarbons, chlorinated and not, in aerobic and anaerobic polluted environments.

7) Basis of biotransformation on heavy metals in polluted sites.

8) Biotechnological processes of industrial interest. Strategies and operative phases associated to their development: selection, improvement and optimization of biocatalysts, selection of feedstocks and medium preparation, fermentation stage and downstream stage.

9) Biochemical, microbiological and technological aspects associated to the industrial production (via fermentation or bioconversion) of aminoacids, vitamins, organic acids, antibiotics and enzymes from conventional feedstocks. Examples of bioconversions processes of industrial relevance.

INDUSTRIAL ECOLOGY M

(Prof. Ernesto Salzano, Prof. Francesco Santarelli, Prof. Alessandro Tugnoli)

- Knowledge about environmental impacts from industrial activities and their evaluation
- Knowledge about the evolution of the environmental policy in EU
- Knowledge about DPSIR model for the analysis and control of pollution process

Course contents:

Sustainable Development: basic elements and open questions; The environmental policy of the European Union; Voluntary programs: Environmental Management Systems (EMAS/ISO14001); Environmental Labels (Ecolabel/EPD); Permitting procedures: Environmental Impact Assessment; Strategic Environmental Assessment; Industrial Emission Directive; Environmental protection through product policies: Integrated Product Policies; Design for the Environment; Extended Product Responsibility;

The main environmental concerns from industrial activities; Global warming: a phenomenological approach; Action to reduce anthropic emissions of green-house gases; Ozone depletion: a phenomenological approach; Photochemical smog: phenomenology and reduction strategies;

Energy production and the environment: connections, impacts, alternative energy sources; Greening the energy production: supply chain and life-cycle approaches; Raw materials for energy production by thermo-chemical processes: fossil fuels, alternative fuels, waste derived fuels and biomasses; Thermo-chemical processes for energy production: combustion and pollutant formation; Plant technologies for energy production: combustion plants, pyrolysis/gasification plants; Emission control and pollution prevention: pre-treatment and end-of-pipe strategies;

The life-cycle approach: perspective, application and limits; The LCA methodology (ISO14040 family); Environmental indexes and indicators; Intensification and integration of processes; Industrial symbiosis; Eco-innovation; Project work: LCA application and tools

INDUSTRIAL SAFETY M

(Prof. Giacomo Antonioni)

This course will provide students with knowledge of the theory and tools for loss prevention and risk analysis of industrial processes. The course will explore the safety implications of material and technology hazards. Students will be provided with the tools needed for the evaluation of the consequences and of the likelihood of accident scenarios, for risk analysis and for risk mitigation.

1) Introduction to loss prevention and risk analysis: Basic notions of safety, hazard and risk. Risk reduction strategies. Inherent safety. The risk assessment procedure. Introduction to relevant regulation.

2) Hazardous properties of substances: Introduction to hazardous properties of materials. Flammability. Toxicity. Environmental damage. The REACH regulation. Classification and labeling of hazardous material. The material safety data sheet.

3) Hazard identification: Available tools for hazard identification. Analysis of case histories. Safety review. Checklists. What-if analysis. HazId analysis. HazOp analysis. FMECA. Fault tree analysis. Event tree analysis.

4) Frequency evaluation and reliability engineering: Basic notions of probabilities and frequencies. Generic frequencies for loss of containment. Random events and part count. The analysis of complex systems by means of fault trees. Introduction to reliability engineering. Non-repairable components. Repairable components. Reliability databases. The Markov model. Preventive maintenance. Human reliability. Systems reliability.

5) Consequence and damage assessment: Source terms models (liquid, gas, mixed-phase release). Dispersion models for neutral and heavy gases. Models for radiative effects from fire scenarios (pool fire, jet-fire, fireball, flash fire). Models for overpressure effects from explosions (physical explosions, BLEVEs, vapor cloud explosions, confined explosions, runaway reactions). Damage models for heat radiation, overpressure and toxic exposure (threshold and probit approach). Model selection criteria. Introduction to consequence assessment software.

6) Quantitative risk assessment: Quantitative risk assessment studies. Risk indicators: individual risk and social risk. Risk re-composition. Risk acceptability criteria. Risk mitigation. Area risk analysis and transportation risk analysis. Examples of application.

INTRODUCTION TO BASIC DESIGN M

(Prof. Valerio Cozzani, Prof. Alessandro Tugnoli)

The course aims at introducing the students to the design of unit operations. An introduction to basic design and process control is provided. Green engineering techniques, design for environment and innovative design techniques introducing sustainability and safety drivers in design will be presented. Design techniques will be applied to the more important unit operation in the chemical and process industry: heat transfer, distillation and absorption.

Course contents:

1) Introduction to basic design concept and documents: Conceptual and Basic Design in FEED context. Elements of a process plant: utilities, process equipment, storages.
2) Approach to basic design of process equipment: Process requirements and constraints for equipment sizing. Economic, environmental and safety constraints. Technical constraints: utilities and specific site constraints. General approach to sizing of equipment.
3) Unit Operations: The concept of unit operations. Brief summary of the more common unit operations applied in the chemical and process industry.
4) Design of process equipment: Procedures for the design of heat exchangers. Procedures for the design of condensers. Procedures for the design of evaporators, vaporizers and reboilers. Procedures for the design of tray and packed columns.
5) Case-studies: For each type of equipment for which design procedures are introduced, a case-study will be presented and the practical application of the design procedures to the case-study will be required. Assessment of costs and selection of best design option will also be addressed in a specific case-study.

LABORATORY OF ADVANCED PROCESS SIMULATION M

(Prof. Giacomo Antonioni)

The course aims to give students the elements to autonomously set-up and analyze time-dependent simulations of chemical processes of environmental or industrial interest with the aid of examples and tutorials.

Course contents:

Introduction to steady-state simulations as set of initial conditions for continuous operations. Basic concepts of dynamic simulation: flow driven vs. pressure driven simulations. Required design specifications that affect the time-dependent behavior of equipment items. Simulations of the transient of single unit operations. Simulations of the transient of small plant sections showing the interaction between different time-varying process variables.

Attendance suggested on the second year.

LABORATORY OF BIOMEDICAL MATERIALS AND TECHNOLOGIES M

(Prof. Paola Fabbri)

At the end of the course the student has skills on the design and test of technologies and materials applied in the biomedical sector..

Course contents:

the laboratory will provide the Student with specific information related to the biomedical field, from specific requirements in design and project development for biomedical devices and technologies, to materials selection and industrial methods of production and fabrication of biomedical objects.

In specific, the course will transfer knowledge on:

The engineering approach for biomedical design. Criteria for materials selection for biomedical applications: specific data bases and data sources. Correlation between materials properties and applications. How to select a proper fabrication process for a biomedical device. Methods and processes for the production of biomedical devices: joint prosthesis, intra ocular lenses, contact lenses, vascular stents, vascular grafts, scaffolds for tissue engineering, bone fixation systems. Specific processes for the biomedical field: aseptic production, clean processing, aseptic packaging, sterilization.

Attendance suggested on the second year.

LABORATORY OF CHEMICAL AND BIOCHEMICAL REACTORS M

(Prof. Dario Frascari)

The course will provide practical skills and knowledge of tools for the design of chemical reactors and equipment for mass transfer operations, for both industrial (chemical, pharmaceutical and food industry) environmental applications.

Course contents

The course, that will take place in the computer lab, will tackle the main design and rating problem relatively to the main types of chemical reactor (batch, plug flow, stirred tank), of chemical reaction (reversible, irreversible, autocatalytic, reactions in series, parallel reactions, biochemical reactions) and of thermal conditions (isotherm reactor, adiabatic reactor, reactor with an assigned thermal flux).

For each topic, after a short introduction that will briefly recall the main theoretical elements, the instructor will present one or more design and rating problems, that the students will solve with the aid of specific software.

LABORATORY OF INDUSTRIAL AND ENVIRONMENTAL BIOTECHNOLOGIES M

(Prof. Giulio Zanaroli)

The course aims to give students the basic elements to develop and optimize biotechnological processes of environmental or industrial interest with examples, exercises and laboratory experiences.

Course contents:

Using literature biotechnological experiments on the remediation of hydrocarbon-contaminated soils and sediments and the production of biomolecules and biofuels as examples, the type and phases of experimental designs, sampling and analytical methods and examples of data analysis and interpretation will be examined. Part of the examples will be focused on factorial design and the application of response surface methodology for the optimization of biotecnological processes based on enzymatic and microbial catalysts.

Attendance suggested on the second year.

LABORATORY OF INDUSTRIAL SAFETY

(Prof. Alessandro Tugnoli)

This course will provide students with the practical application skills in loss prevention and risk analysis for industrial processes.

Course contents:

The concepts learned in the previous Industrial Safety courses will be applied to concrete case studies. The students will use the main tools in risk assessment and will learn about the typical issues in its practical application. The course unfolds around problem-based learning activities in small groups to develop a project.

Detailed program:

1) Introduction

Basic review of the quantitative risk assessment procedure. Risk reduction strategies and design for safety. Introduction to relevant regulations. Assignment of a case-study.

2) Analysis by hazard and risk indicators

Review of the main hazard and risk indicators. The Mond Index. Application to the case-study.

3) HazOp and bow-tie analysis

Review of the HazOp analysis. Fault tree analysis. Event tree analysis. Application to the case-study.

4) Frequency evaluation

Frequency quantification of the bow-tie diagrams. Analysis of the relevant databases for frequencies. Application to top-events in the case-study.

5) Consequence and damage assessment

Review of accident scenarios. Review of main consequence and damage models. Consequence assessment software: use and simulation. Application to the case-study.

6) Risk assessment

Risk re-composition. Risk index calculation. Analysis of the possible risk mitigation initiatives. Application to the case-study.

LABORATORY OF MATERIALS CHARACTERIZATION M

(Prof. Stefania Manzi)

The laboratory provides the students with the know-how and the methodological tools for the characterization of materials, for their correct use in the engineering fields.

<u>Course Contents:</u>

Tests for the investigation of the nature and microstructure of materials (absolute and bulk density, water absorption, mercury intrusion porosimetry, laser grain size distribution analysis, SEM + EDX, abrasion test, XRD, etc.).

Tests for the investigation of the mechanical properties of materials (strength test, impact test, hardness test, etc.).

Tests for the investigation of the thermal properties of materials (DSC, TGA, dilatometry, etc.).

Tests for the investigation of the electrical properties (electrical conductivity in c.c., dielectric constant, loss factor).

Ageing and durability tests on materials with relation to their environment.

Attendence suggested on the second year.

LABORATORY OF MOLECULAR DESIGN AND MATERIALS SIMULATION M

(Prof. Maria Grazia De Angelis)

Introduction to statistical mechanics. Ensembles. Partition functions. Averages.

Correlation between microscopic and macroscopic approaches: thermodynamic laws derived from microscopic quantities.

Introduction to Molecular Dynamics (MD) simulation: idea, initialization, force fields.

Integrating the equations of motion: algorithms.

MD of Atomic systems, hard spheres, hard non spherical bodies.

Calculation of forces, energies, pressure. Calculation of free energy and chemical potential. NPT and NVT molecular dynamics.

Examples of application: Vapor-liquid equilibria, gas solubility, polymers, pressure-volume-temperature behavior , diffusion, adsorption, biological systems, chemical reactions.

Use of Commercial Software to evaluate thermodynamic properties of substances. Use of Amorphous builder and of the LAMMPS simulation engine. Analysis of the results.

Elaboration of a final project.

Attendance suggested on the second year.

LABORATORY OF OFFSHORE OPERATIONS

(Prof. Valerio Cozzani)

The student will be introduced to the main construction and maintenance operations in off-shore activities with the aim of understanding the specificities required by off-shore operations.

LABORATORY OF PHOTOCATALYSIS M

(Prof. Giovanni Camera Roda)

The purpose of the course is to give the students the basics and the skill of operating on photocatalytic processes, which nowadays are increasingly important for many applications ranging from detoxification and self-cleaning materials to green chemical synthesis. The course proposes both a theoretical approach (mechanisms of photocatalysis, engineering of photocatalytic devices and presentation of existent or proposed practical applications) aimed to the knowledge of process fundamentals and some laboratory experiences, where the principles are verified and analyzed. his course will provide students with the practical application skills in loss prevention and risk analysis for industrial processes.

Course contents:

Basics of photocatalysis:

Definition of Photocatalysis. Photocatalysis as an Advanced Oxidation Technology.

Kinetics: Rate of reaction and relevant parameters. Photodifferential reactor for the kinetics analysis.

Slurry reactors and Immobilized Photocatalyst: Comparison (Pros and Cons). Techniques of deposition of films.

Natural and artificial light. Functional wavelengths.

Radiant Energy Transfer and the relative balance equation (Radiation Transport Equation RTE). Methods for the solution of the RTE.

Design of a Photocatalytic Reactor: Choosing the Optical thickness. Optimal Thickness of a Photocatalytic Film. Yields and Effectiveness Factors of a Photocatalytic Reactor.

Detoxification by Photocatalysis: Photocatalysis in aqueous streams. Photocatalysis for gaseous effluents Passive utilization of building materials functionalized for photocatalytic activity.

Photocatalytic Self-Cleaning Materials.

Integrated processes: Process Intensification by Integration of Photocatalysis with Separation Processes or other Advanced Oxidation Technologies.

Laboratory experiences:

1. Experiments: a) Kinetic analysis with a photocatalytic differential slurry reactor; b) Deposition of a photocatalytic film by the sol-gel method; c) Photocatalytic synthesis of vanillin; d) Air depuration by photocatalysis.

2. Mathematical modeling: a) Solution of the radiant energy transport equation to obtain the LVREA distribution; b) Solution of the local mass balance inside a photocatalytic reactor.

LABORATORY OF THERMODYNAMIC SIMULATION M

(Prof. Marco Giacinti Baschetti)

At the end of the course the student has skills on the selection of thermodynamic models for process simulation and on the thermodynamic analysis of processes.

Course contents:

The laboratory of thermodynamic simulation will focus on the following topics:

- Brief introduction of the different modeling approach for the study of pure components and mixture properties: the equation of state approach and the models for the estimation of activity coefficients of different compounds in mixtures.
- Implementation of simple models in different mathematical software and application for the prediction pure components and binary mixtures gas-liquids, liquids liquids equilibrium in different environmental condition.
- Description of the different models available in commercial software for process simulation, introduction to the criteria for their choice as a function of the type of process a considered and application for the solution of simple thermodynamics problems involving multicomponent mixtures.

The course will be carried out through short introductory lessons followed by the execution of computer based exercises focused on model implementation and application to describe different type of experimental data and to solve simple thermodynamic problems.

Attendance suggested on the second year.

MATERIALS CHARACTERIZATION M

(Prof. Antonio Motori)

Course contents:

Measurement of physical properties

1) Standards and dimensional units of measurement.

2) Assessing and presenting experimental data. Analysis of the common types of error. Statistical treatment of experimental data: probability distribution. Normal, Weibull, t-Student, Chi-Squared distribution functions. Examples.

Measurement of mechanical properties

1) Stiffness: stress and strain. Tensile, compression, flexural and torsion tests. Apparatus and procedures for testing of mechanical properties. Deformation and fracture of engineering materials. Yield and fracture in tensile tests. Standard test methods. Examples.

2) Elements of fracture mechanics. Linear Elastic Fracture Mechanics (LEFM) and Elastic-Plastic Fracture Mechanics (EPFM). Apparatus and procedures for the evaluation of the critical parameters K c, G c and J c. Standard test methods. Examples.

3) Impact strength. Apparatus and procedures for Charpy and Izod tests. Impact tests for fracture mechanics investigation. Standard test methods. Examples.

4) Cyclic stress and strain fatigue. Wohler diagrams. Fracture mechanics and fatigue crack propagation. Apparatus and procedures for fatigue tests. Standard test methods. Examples.

5) Viscoelastic properties. Dynamic moduli. Apparatus and procedures for the evaluation of viscoelastic properties. Examples. Rheological properties. Apparatus and procedures for the evaluation of rheological properties. Examples.

6) Surface properties. Hardness. Wear. Apparatus and procedures. Standard test methods. Examples.

Measurement of thermal properties

1) Thermal expansion. Specific heat. Thermal conductivity. Glass transition temperature. Melting temperature. Apparatus and procedures. Standard test methods. Examples.

2) Measurement of electrical properties.

3) Electrical conductivity, dielectric constant and loss factor, dielectric strength. Apparatus and procedures. Standard test methods. Examples.

4) Investigation of microstructural properties.

5) Optical microscopy. Electron microscopy and microanalysis. Examples.

MATERIALS CHEMISTRY M

(Prof. Maurizio Fiorini)

The Materials Chemistry course addresses inorganic, organic and nano-based materials with a structure vs. properties approach, providing a suitable breadth of coverage of the rapidly evolving material fields. A few examples are: Advanced polymeric materials such as polymer matrix nanocomposites containing layered fillers (such as phyllosilicates and layered double hydroxides,) or carbon-based nanofillers like nanotubes, graphenes and fullerenes. From the application point of view, such novel materials may take on an increasingly important role in frontier research fields like solar energy harvesting in organic solar cells, and organic conductors in devices currently based on silicon semiconductors (like OLED, flexible displays, smart electrochromic windows). Nano-based materials will be introduced with a focus on the two different approaches to prepare them: top-down and bottom-up assembling of individual building blocks into more complex architectures. Solid state chemistry, with its traditional emphasis on crystalline structures featuring the most important archetypical unit cells, fundamental principles of X-ray diffraction and band model, still deserves some attention in this Materials Chemistry course, but it is paired with an amorphous-solids section to include up-to-date concepts in sol-gel synthesis techniques in the field of thin film preparation or surface modification.

<u>**Course Contents:**</u>

1) Amorphous and crystalline solids. Symmetry; the main symmetry elements. Lattices; unit cell; Bravais lattices. Miller indices for planes and lattice directions.

2) Review on packing of atoms, close-packed structures. ionic crystals and their main structures (rocksalt, fluorite, blende, wurtzite, rutile, ReO3; mixed oxides: perosvkite and spinels). Silicates.

3) Bonding in solids. Ionic solids; the role of ion size; Shannon-Prewitt model for ions. Transition metal compounds and non-bonding electron effects. Crystal field theory. Band model for metals and semiconductors.

4) Crystal defects and non-stoichiometry. Role of point defects in diffusion in solids. Ionic conductivity. Some important solid state electrolytes for batteries and fuel cells.

5) BASED MATERIALS: conducting polymers, structure and properties. Polymer electrolyte for Li batteries. Proton conducting polymers for fuel cells electrolytes. Fullerenes and fullerides, synthesis and properties. Carbon nanotubes, graphene and their application in polymer nanocomposites.

6) LAYERED SOLIDS: layered double hydroxides, clays and their modification to improve the compatibility with polymers. Preparation of polymer nanocomposites using organoclays. Flame retardant properties of LDH and organoclay based polymer nanocomposites.

MODELLING OF OFFSHORE STRUCTURES

In the course, element for modelling of offshore structures will be given. Three main parts of the course will be: equivalent static and dynamic modelling of the actions, including wave action and wind, both in the time and frequency domains; finite element modelling of the structure, stress and displacement recovery and verifications; modelling and verifications against cyclic loadings, with special emphasis to fatigue and damage of metallic materials.

Content

Introduction to structural solutions in the Offshore Environment: Platform typologies; Moorings; Pipelines. Environmental Actions on Offshore Structures: Buoyancy and gravity; Fluid-induced structural forces (waves, currents and winds); Earthquakes, ice impact and wave slamming; Deterministic and statistical descriptions of offshore waves. Dynamics of Offshore Structures: Deterministic responses for single degree of freedom structures in time and frequency domain; Statistical responses for single degree of freedom structures; Responses of multi-degree of freedom linear structures. Finite Element Modelling of a fixed-bottom platform: Members, joints and mass modelling; Actions modelling (permanent loads, wind, waves and currents, soil-structure interaction); Types of Analyses (static and quasi-static linear analysis, natural frequency, dynamically responding structures, non-linear analysis). Fatigue Assessment of Offshore Structures: Fatigue strength based on S-N curves; Damage accumulation rule and fatigue safety checks; Deterministic, simplified and spectral fatigue assessment methods; Stress concentration factor determination; Fracture mechanics approach.

MONITORING AND POSITIONING IN OFF-SHORE ENGINEERING

(Prof. Stefano Gandolfi, Prof. Luca Vittuari)

This course provides theoretical and operatives knowledges concerning the monitoring and positioning aspects in the offshore engineering. In particular, different techniques for an accurate positioning based on GNSS technology will introduced both for monitoring of off-shore structures and for geolocalization of off-shore infrastructures. Examples of real applications regarding the monitoring or the positioning of offshore structures will be discussed.

Content

Geodetic Reference Frame for positioning and monitoring: Basic of Global and Local Geodetic Reference Frames: definition, realization and characterization. Use of the different reference frames for off-shore structural monitoring, subsidence monitoring and off-shore positioning

Instrumentation and technologies for survey and positioning in off-shore engineering

Classical Instrumentation and survey methods: Total Station and Spirit Levelling, application of the classical techniques in off-shore industry

GNSS: GNSS observables (Pseudorange & Carrier phase), Impact of propagation Media (Troposphere, Ionosphere), Concepts on GPS carrier phase data Processing ,Concepts on GNSS carrier phase within codes data processing (Precise point Positioning), Elements of Adjustment computation. Use of GNSS technique in off-shore Engineering.

Other sensors for subsea or subbed investigation: Elements of echo sounding for bathymetric surveys and Seismic

Basic principles for sensors coupling

Applications and examples in the field of Monitoring and Positioning in off-shore Engineering.

NUMERICAL METHODS M

(Prof. Fiorella Sgallari)

A successful learner from this course will be able to: a) deal with numerical analysis topics such as: accuracy, truncation and round-off errors, condition numbers, convergence, stability, curve-fitting, interpolation, numerical differentiation and integration, numerical linear algebra; b) deal with numerical methods for solving ordinary and partial differential equations, with finite difference and finite element methods for parabolic and elliptic partial differential equations.

<u>Course Contents:</u>

1) Key idea: accuracy, precision, truncation and round-off errors, condition numbers, operation counts, convergence and stability.

2) Numerical Linear Algebra: direct and iterative methods for linear systems.

3) Solution to single equations and multiple non-linear equations.

4) Interpolation and approximation: interpolating polynomials, cubic splines, least-square fitting.

5) Numerical differentiation and integration: Newton-Cotes quadrature formulas, Gaussian quadrature.

6) Classification of PDEs: elliptic, parabolic and hyperbolic equations.

7) Finite difference methods. Stability, consistency, and convergence theory.

OCEAN AND COASTAL ENGINEERING

(Prof. Renata Archetti, Prof. Alberto Montanari)

The course aims to provide tools and skills for the design and management of coastal and ocean structures, as well as the assessment of their impact. The course will introduce and describe the processes that characterize the oceanic and coastal environment and will provide tools for the analysis and design of coastal defenses, offshore structures, offshore and onshore approach facilities, and renewal energy plants. In particular the student will be able to analyze the sea conditions (waves, currents) and to design coastal and ocean structures, as well as harbors, breakwaters, offshore structures (TLP, offshore). Particular attention will be dedicated to environmental impact assessment. The conversion of energy from the sea (waves and currents) will also be treated.

Content

Introduction to the Course. The Coastal environment. Wind. The geostrophic approximation. Geostrophic wind. Measure of the wind. Force of the wind on the structures. Sea water level: astronomic and meteorological components. Astronomical tides, effects of the Moon and the Sun. Components. Wave. Linear Theory. Dispersion relationship. Shallow water and deep water approximation. Wave generation. Fetch. Effective and geographical fetch. SMB methods. Exercises on wind waves generation. Harbor engineering. Lay out for industrial and marine piers, pontoons. Maneuvers to enter in the ports. Breakwaters (rubble mound and vertical). Moorings. Harbour and offshore docks. Design of coastal structures. Environmental impact assessment of coastal structures.

Introduction to ocean engineering. Irregular waves. Wave statistics. Non-linear theory of waves. Observation of the sea environment: waves, drifters, tide gauges. Floating Structures: Wave forces & motions theory. Interaction of waves with Offshore structures TLP Sparbuoys. Principles of energy conversion from the sea, in particular Wave energy conversion. Environmental impact assessment of ocean structures. Case-study: preliminary design of a coastal and/or ocean structure. One or more visit to a company leader in offshore or marine engineering.

OFF-SHORE ENGINEERING AND HSE MANAGEMENT M

(Prof. Renata Archetti, Prof. Valerio Cozzani)

The aim of the course is to introduce the student to the general themes of off-shore engineering and to provide specific knowledge on the Health, Environmental and Safety issues in off-shore operations, also focusing on those related to the production of Oil&Gas resources.

Course Contents:

Introduction to Off-Shore Engineering

Processes that characterize the coastal environment and the beach evolution processes. Introduction to marine and ocean environment.

HSE Management

Introduction to HSE issues and management: Health, Environmental and Safety and its domain, Quantitative Risk Assessment, relevant standards and regulations.

Material and Process Hazards: hazardous properties of oil & gas materials, hazard identification techniques, inherent safety and risk reduction.

Health in off shore facilities: occupational safety issues, transportation risks, fatal accident rates, fugitive emissions, task analysis, safety culture.

Safety in off shore facilities: major accident scenarios, evaluation of accidental frequencies, evaluation of consequences in fire scenarios, evaluation of consequences in explosion scenarios, evaluation of consequences in toxic release scenarios, human vulnerability and risk evaluation.

Environmental protection in off shore facilities: evaluation of accidental frequencies, evaluation of consequences in spill scenarios, environmental risk assessment.

Loss prevention and risk reduction: passive protection strategies, active protection strategies, safety procedures and human error, personal protection devices, emergency management.

PETROLEUM GEOSYSTEM M

(Prof. Viliam Bortolotti, Prof. Paolo Macini, Prof. Ezio Mesini)

The course is addressed to provide the basic knowledge of petroleum systems and petroleum engineering, with special reference to exploration, drilling and production engineering. These topics represent strategic elements as far as world energy supply is concerned. The Course is completed with an introduction to the study of petroleum economics, project management and engineering phases of the petroleum industry, with applicative exercises and laboratory practices.

Course contents:

1) Origin and geology of petroleum reservoirs. Overview of E&P industry (Upstream) and basics of petroleum economics and project management. Petroleum exploration techniques. Introduction to petroleum well drilling engineering (onshore and offshore).

2) Introduction to the study of natural porous media. Oil and natural gas reservoir rock properties. Porosity, permeability, saturation, capillary pressure, wettability, multi-phase flow. Laboratory measurements and lab practice.

3) Thermodynamic classification of hydrocarbon reservoirs. Phase behaviour and reservoir distribution of petroleum fluids. Oil and natural gas reserves estimation. Simulation of reservoir behavior using numerical modeling: basic concepts of discretization, numerical simulation of single- and multi-phase flow, model calibration and history matching. Basics of formation evaluation. Well logging and logging while drilling. Overview of petroleum production and transportation systems.

POLYMER SCIENCE, TECHNOLOGIES AND RECYCLING M

(Prof. Andrea Saccani)

The aim of the course is the discussion of the concept of macromolecule. Chain macro- and micro-structure are examined and correlation are built with the thermal and mechanical behaviour of the material. The implication on material life-cycle are also introduced.

Course Contents:

1) Concept of macromolecule. Synthetic and natural polymers.

2) Polymers from renewable resources

3) Polymerization Step-growth and Chain growth mechanisms Kinetics. Examples

4) Structure of polymeric chains. Conformations and configurations Morphology.

5) General relationships between structure and properties

6) Molecular weight. Definitions and experimental determination

7) Crystallization, melting and glass transition

8) Mechanical properties

9) Temperature dependence Ultimate properties. Elastic modulus. Yielding process

10) Viscoelastic behaviour Creep and stress relaxation processes

11) Degradation

12) Recycling

PROCESS ANALYSIS FOR ENERGY AND ENVIRONMENT M

(Prof. Giacomo Antonioni, Prof. Ernesto Salzano, Prof. Alessandro Tugnoli)

The aim of the course is to provide the students with a basic knowledge of the tools for the analysis of industrial processes. The introduced process analysis tools will be aimed at the integrated assessment of technological, economic, environmental, and safety drivers, orientating process design and allowing for the assessment of process sustainability.

Course Contents:

1) Introduction: Definition of an industrial process in the context of the chemical, energy and environmental sectors. Process boundaries and interfaces. Continuous, batch and semi-batch processes. Process operations, process units and process streams. Process technological issues, aims and impacts. Tools for process representation: Block Diagrams and Process Flow Diagrams.

2) Energy and Mass Balances: Basic definitions. System and surroundings. Types of flow. Balance equations. Scale of balance equations. Mass balance and energy balance. Application of energy and mass balance to process analysis.

3) Process economics: Assessment of production costs. Operating costs and capital costs. Assessment of process operating costs. Assessment of capital costs of equipment. Analysis of investment and basic indicators of process economic performance.

4) Environmental impact: Assessment of process environmental impacts. By-products and non-renewable raw-material consumption. Side-streams and emissions. Fugitive emissions. Link with LCA perspective. Key performance indicators for environmental performance.

5) Safety: Assessment of process safety and of major accident hazards. Hazard identification and preliminary risk assessment. Key performance indicators for safety performance.

6) Process simulation and analysis: Introduction to the Hysys software. Application to the simulation of a case-study. Assessment of key performance indicators and of process sustainability.

PROJECT MANAGEMENT IN OFFSHORE ACTIVITIES

(Prof. Alessandro Grandi)

The student will be introduced to the management of projects in the specific framework of the off-shore industry, with the aim of understanding the activities required to effectively manage a large-scale off-shore project.

SOLID STATE ELECTRONICS M

(Prof. Massimo Rudan)

Knowledge about the fundamentals of quantum mechanics and band theory of solids; knowledge about the physical phenomena underlying the transport of charged carriers in solids.

Competencies: (general) to have critical understanding of technical and scientific tools; to be able to select and apply numerical TCAD tools; communication skills; to be able to work in an international context; (specific) to understand the methods for investigating advanced solid-state devices; to determine the important microscopic and macroscopic parameters involved in the functioning of semiconductor devices; to perform numerical analyses of semiconductor devices.

Detailed contents: introductory part where the basic relations of quantum mechanics are shown; theory of bands in crystals; description of the different hierarchical approached to the transport theory; lattice vibrations; treatment of the main scattering mechanisms in semiconductors; absorption of light in semiconductors; derivation of the macroscopic elastic properties of solids. Case studies of solid-state device modeling using advanced professional software tools.

SOLID STATE PHYSICAL CHEMISTRY

(Prof. Renato Colle)

At the end of the course, the student knows basic concepts, mathematical structure and computational methods of quantum mechanics and solid state physics; they also acquire knowledge of quantum transport theory and chemical reactivity, as well as information on recent research and open problems in the applications of the theoretical methodologies to the study of materials interesting for nanoelectronics and energetics. The student is able to use this knowledge to formulate and solve problems concerning structural, electronic and optical properties of atoms, molecules and crystals. They are also able to tackle simple problems of quantum transport in nanoelectronic devices, molecular dynamics and chemical reactivity.

Prerequisites:

Prerequisites: basic knowledge of classical physics, differential and integral calculus, linear algebra and chemistry are requested.

Course Contents:

1) BASIC QUANTUM MECHANICS: Concepts and postulates - Measurements of observables - Mathematical formalism - Symmetry and angular momenta - Matrix quantum mechanics -Wave mechanics in position and momentum representations: time independent Schroedinger equation - Time evolution of quantum states: time-dependent Schroedinger equation - Quantum molecular dynamics.

2) APPLIED QUANTUM MECHANICS: Methods for approximate solutions of time independent Schroedinger equations: Hartree-Fock method and Density Functional Theory –

Calculation of energy levels and electronic state of atoms and molecules - Calculation of roto-vibrational states of molecules - Light-matter interaction - Chemical reactivity.

3) ELEMENTS OF SOLID STATE PHYSICS: Crystallography: definition of crystal - crystal lattices in direct and reciprocal space: primitive vectors, primitive cells, unit cells - Bravais lattices - point and spatial symmetries and groups - Miller's indices. Quantum mechanics of periodic systems: one-electron approximation and Bloch theorem - Energy bands and density of states - Electronic properties of selected crystals - Lattice dynamics of crystals -Transport properties of electrons and phonons - Optical properties of semiconductors.

4) ELECTRONIC TRANSPORT IN NANODEVICES: Model of nanoscale field effect transistor - An atomistic view of the electrical resistance - Energy levels diagram - Flow of electrons and rate equations - Current in one-level channel - The quantum of conductance - Landauer formula - Potential profiles and iterative procedures for calculating the I/V characteristic - Coulomb blockade - Calculation of current in multi-level channel.

TECHNOLOGY AND SUSTAINABILITY OF COMPOSITE MATERIALS M

(Prof. Antonio Motori)

Knowledge of properties, application and manufacturing technology of main composite materials. Comprehension of the mechanisms which allow to obtain particular properties on the basis of material components and their architecture. Ability in the choice of the most suitable composite material on the basis of the technological requirements of the product.

Course Contents:

1. General characteristics of composite materials. Structure and properties of metal, ceramic and polymer matrix.
2. Structure and properties of the main particles and fibres used in composites. Natural fibres and sustainable composites. Microstructure of composite materials. Interfaces and their effects on the properties of composites. Concepts on mechanics of anisotropic materials. Lamina and laminates. Models for the estimation of the properties of thin laminates, based on the properties of matrix and dispersed phase.
3. Main fabrication processes, properties, design concepts and applications of composite materials.
4. Measurement of chemical-physical and mechanical properties of composites. Tests and Standards.
5. Recycling and sustainability of composite material.

THERMODYNAMICS OF ENERGY AND MATERIALS M

(Prof. Maria Grazia De Angelis)

Thermodynamics governs energy transformations and the time evolution of the systems, requires precise constraints among the different state properties of matter and determines the final equilibrium states reached under proper external conditions. From a surprisingly small set of empirically based laws, an enormous amount of information about the relationships among equilibrium parameters for a system can be deduced. This information can then be applied to physical, chemical and biological systems including engine design, materials processing and cellular processes. Thermodynamics is a macroscopic theory, independent of any molecular model of matter, but molecular interpretations of various properties (*e.g.*, entropy and temperature) will be discussed in the course to broaden intuitive understanding. The focus of this course is the further development of advanced thermodynamics.

The objective of this course is to review the principles of thermodynamics and to apply them to advanced chemical engineering processes.

Course Contents:

The first law of thermodynamics, enthalpy, and heat capacity; energy balances with and without chemical reaction. The second laws of thermodynamics and its consequences on material properties: ideal gas and real fluid behavior for viscous fluids. Thermodynamic properties of solids, viscoelastic fluids; polymers and fluids with entropic elasticity. The second laws of thermodynamics and its consequences on process analysis: minimum/maximum work issues, energy cycles, refrigeration cycles, cryogenic cycles. The second laws of thermodynamics and its consequences on process analysis and stable equilibria: equilibrium criteria and equilibrium conditions for pure components, mixtures (without and with reactions). Solution of advanced chemical engineering process problems using material properties at low and at high pressures, for real fluids. Solution thermodynamics and phase equilibria with solutions (liquid-vapor, liquid-liquid, L-L-V, liquid-solid...). Reaction thermodynamics. Thermodynamics of interfaces and interphase phenomena. Interfacial Thermodynamics; Kelvin Equation; Freezing Point Depression of Nanocrystal. Polymer-Polymer Blends. Solute-Solid Adsorption Equilibrium; Thermodynamics and Chromatography. Electric field induced phase separations. Fuel Cells. Chemical Reaction Equilibrium – Multiple Reactions and Applications of Chemical Reaction Equilibrium to Reactor Design.

TRANSPORT PHENOMENA LABORATORY M

(Prof. Matteo Minelli)

Understanding fundamental characteristics of Computer Fluid Dynamics (CFD) formulation of heat and momentum transport in fluid flow.

Knowledge of steps in CFD procedure for the solution of thermo-fluid mechanics problems.

Gaining experience in use of CFD software and in interpretation of results for the discussion of generalized transport laws.

<u>**Course contents:**</u>

1) Basic elements of control volume formulation for the discretization of PDE for heat and momentum transport in continuum media (implicit-explicit formulation; up-wind, power law and exponential schemes, coupled and separated options, residual treatments and convergence criteria)
2) Geometry definition, mesh creation and post processing operations
3) Examples of CFD formulation and solution for steady state 2D laminar momentum transport problems
4) Use of CFD tools for the simulation of fluid mechanics problems for newtonian fluids and retrieve of generalized laws for Fanning coefficient
5) Examples of CFD formulation and solution for steady state 2D heat transport problems in fluid flow
6) Use of CFD tools for the simulation of fluid thermo-fluid mechanics problems for newtonian Fourier fluids and retrieve of generalized laws for Fanning coefficient and Nusselt number
7) Examples of CFD formulation and solution for steady state 3D heat transport problems in fluid flow
8) Examples of CFD formulation and solution for unsteady 2D heat transport problems in fluid flow

TURBOMACHINES AND POWER GENERATION FOR OFF-SHORE APPLICATIONS M

(Prof. Michele Bianchi)

The course is aimed at providing basic principles for design and operation of typical fluid machines used for “island” application in off-shores installations

Course Contents:

Compressor Thermodynamics

Ideal gas modeling, compression isentropic and polytropic efficiency, T-s diagram, h-s diagram.

Compressor types, classifications, performance and applications

Compressor types: continuous flow compressors (ejectors, axial flow compressors, centrifugal compressors, mixed flow compressors), positive displacement compressors (reciprocating compressors, sliding vane compressors, lobe compressors, etc.), compressor performance: positive displacement, dynamic (centrifugal and axial compressor)

Gas turbines

Brayton cycle (lay out, thermodynamic analysis, performance evaluation), heavy duty and aeroderivative gas turbines, effect of ambient condition on gas turbine performance, gas turbine power augmentation techniques.

Combined heat and power

Basics of combined heat and power (CHP) production, CHP systems, performance and applications.

Storage techniques from renewable generator

Electrical energy devices typologies, performance, operational strategies, ect. Integration of energy storage with wind and photovoltaic generators.