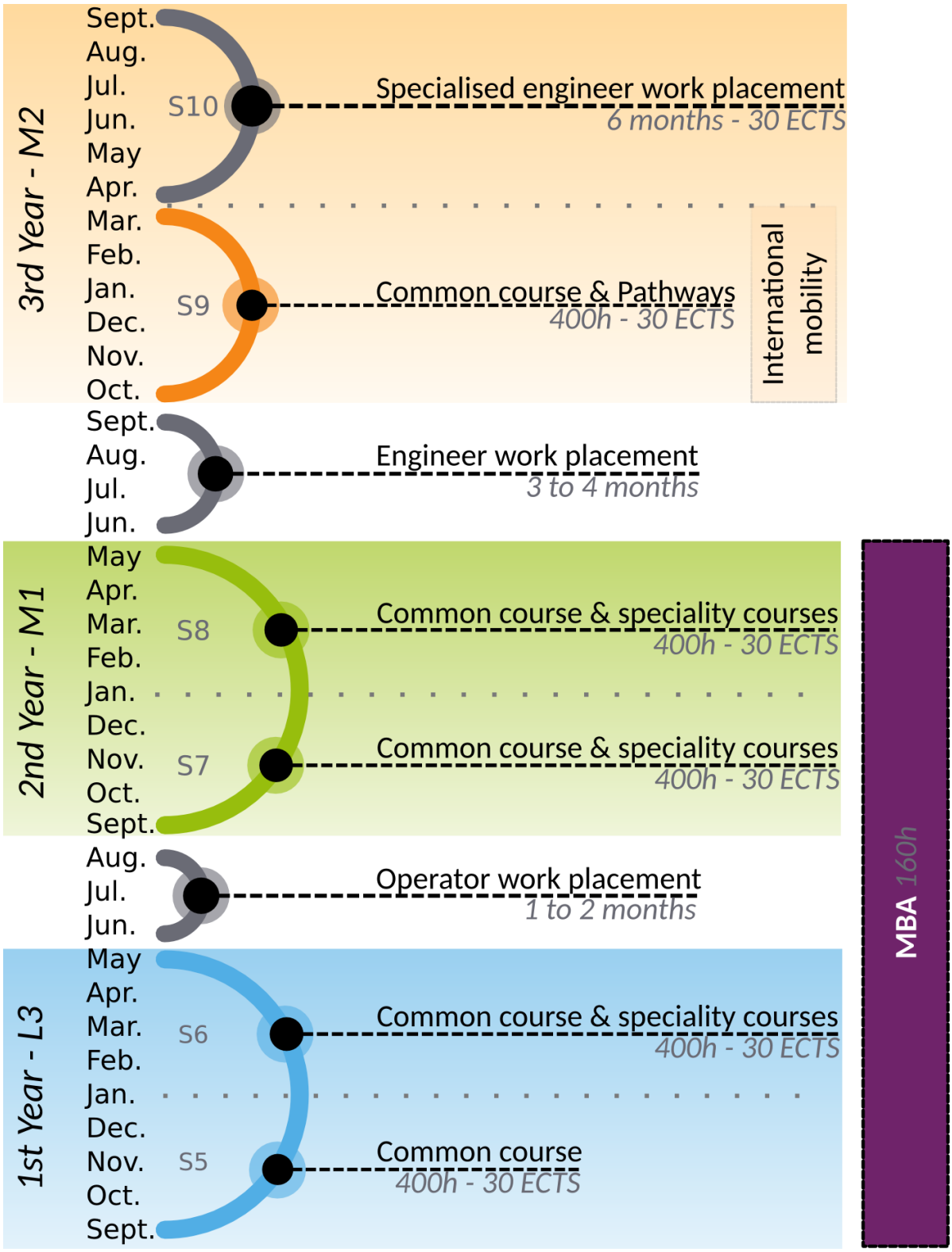
Ecole Nationale Supérieure en Génie
des Technologies Industrielles

COURSE CATALOGUE

First Year (Sem. 5 and 6)

GENERAL CHRONOLOGY



CPGE – DUT – L3

NOMENCLATURE FOR ASSESSMENT PROCEDURES

Nature_1 (Modality_1) x Weighting_factor_1 + Nature_2 (Modality_2) x Weighting_factor_2 + ...

Assessment nature

CC: Continuous Assessment

Proj: Project

Sta: Work placement

TP: Practical Examination

CoE: Reading Comprehension (languages)

CoO: Listening Comprehension (languages)

ExE: Writing (languages)

ExO: Speaking (languages)

IntO: Oral Interaction (languages)

Cert: Certificate of competency in languages

EvaC: Skills assessment

Assessment modalities

EE: Written examination (by default, if no information provided)

EO: Oral examination

EM: Engine examination

ES: Surprise written examination

PA: Active participation

Sout: Oral defense

Rap: Written report

Prog: Computer program

Tr: Work (within the framework of a work placement, a project or practical work)

D: File

CR: Report (within the framework of practical work)

LA: Reading articles

sd: no document is allowed (by default, if no information provided)

da: documents are allowed (da: further details on the authorized documents)

st: no smart object is allowed (mobile phones, smartwatches...) (by default, if no information provided)

ta: smart objects are allowed

sc: no calculator is allowed (by default, if no information provided)

ca: calculators are allowed

Operators

x/y: x or y

max(x, y): Maximum in several assessments

moyenne(x): Average of several assessments of the same kind and coefficient

Examples

CC (EE, 2h)

A 2-hour written examination, no document allowed, no calculator allowed.

CC (EM, 2h, da:tutoriels) x 1/2 + CC (EE, 2h) x 1/2

A 2-hour engine examination, tutorials are allowed, coefficient 1/2 and a 2-hour written examination, no document allowed, no calculator allowed, coefficient 1/2

CC (ES, 15mn) x 1/10 + CC (EE, 2h, da:tous, ca) x 9/10

A 15-minute surprise examination, no document allowed, no calculator allowed, coefficient 1/10 and a 2-hour written examination, all documents allowed, calculator allowed, coefficient 9/10.

TP(EO, 10mn) x 1/4 + TP(EO, 10mn) x 1/4 + TP(CR) x 1/2

Practical work assessed by two oral examinations, each with a coefficient 1/4, and a practical work report, coefficient 1/2.

Proj (PA, Rap, Sout)

Project assessed by the active participation, a written report and an oral defense.

Sta (Tr, Rap, Sout

Work placement assessed by work, a written report and an oral defense.

CoE(PA) x 1/4 + CoO(PA) x 1/4 + ExE(EE, 1h) x 1/4 + Cert(TOEIC) x 1/4

Example for a foreign language: Reading comprehension assessed by the active participation, Listening comprehension assessed by the active participation, Writing assessed by a 1-hour written examination, no document allowed, Test of English (TOEIC). Same weighted grades for each assessment.

SEMESTER 5

SEMESTER MODULES

COMMON COURSE or ELECTIVE	MODULE CODES	MODULE TITLES	ECTS
Com. Course	EC15LC	Languages - Engineering Culture S5	4
Com. Course	EC15MI	Mathematics - Computer Sciences S5	6
Com. Course	EC15TB	Thermodynamics – Balances S5	10
Com. Course	EC15TM	Transport Phenomena – Mechanics S5	10

MODULE :

Languages - Engineering Culture S5

ECTS : 4		MODULE CODE : EC15LC

MODULE LEARNING OUTCOMES:

- Demonstrate the ability to communicate in English
- Understand the basic principles of accounting

MODULE COURSES

COURSE CODES	COURSES
EC15LC1	English
EC15LC2	Financial Management I

Module: LANGUAGES - ENGINEERING CULTURE S5		EC15LC	ECTS: 4
Course: ENGLISH		EC15LC1	Coeff.: **0,500**
LECTURERS(S): **DELAMBRE Y.**			
Lec.: h	Prac.: **26** h	Lab.: h	Proj.: h
Mandatory Course		Language : English	

OVERVIEW

The focus of this class is to strenghten the English skills to successfully pass the official TOEIC (Listening and Reading) Test of English for International Communication.
The TOEIC is correlated to the Common European Framework of Reference for Languages (CEFR).

LEARNING OUTCOMES

The student masters the technical skills required for the TOEIC test and gains confidence to improve his/her final score.
The student can communicate in everyday workplace situations in a professional environment.

DESCRIPTION

The course is based on Business English and covers vocabulary and grammar useful for the business environment. Oral expression.
Specific intensive training for the TOEIC test as well as mock exams.

ASSESSMENT

CoOx1/5 + ExOx1/5 + IntOx1/5 + CoEx1/5 + ExEx1/5

RECOMMENDED READING

Pearson: Preparation for the New Toeic Test and Market Leader
Macmillon: Business grammar Builder and Business Vocabulary Builder

PREREQUISITE

Level intermediate to advanced (A1 to C2)

Module: LANGUAGES - ENGINEERING CULTURE S5	EC15LC	ECTS: 4
Course: FINANCIAL MANAGEMENT I	**EC15LC2**	Coeff.: **0,500**
LECTURERS(S): **BRETON J.**		

Lec.: **20** h	Prac.: **10** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The aim of the course is to introduce accounting documents for your future business and the language and notions you will have to understand such as: depreciations, budgetary accounting, income statements, balance sheets,...
The course is based on the understanding of notions and concepts you will both have to master and put into practice. It revolves around a classical working business on the French territory with operations like understanding of general accepted accounting principles.

LEARNING OUTCOMES

Giving the students the opportunity to understand the situation and decisions of a company taking its economical, political and legal environment into account.
Apprehend the great rules of financial management :
- master basic accounting principles
- register accounting operations
- be able to formulate and analyze the main synthesis documents

DESCRIPTION

Chapter 1 : Accounting principles
Chapter 2 : Accounting documents
Chapter 3 : Accounting methods and organisation
Chapter 4 : Value added tax
Chapter 5 : Purchases and sales operations
Chapter 6 : Payments and receipts : the treasury
Chapter 7 : Fixed asset management
Chapter 8 : Inventory

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

• « La comptabilité générale 2014-2015 », F. Grandguillot et B. Grandguillot, Gualino, 2014 ;
• « Techniques comptables : DUT GEA 1ère et 2ème année », P. Arnaudo et L. Cassio, Nathan, 2010 ;
• - Exercices d'ouvrages généralistes de BTS CGO (éditions Nathan ou Foucher Plein Pot), de DUT GEA, de DCG chez DUNOD ou de Licence universitaire.

PREREQUISITE

MODULE :

Mathematics - Computer Sciences S5

ECTS : 6	MODULE CODE : EC15MI

MODULE LEARNING OUTCOMES:

- Demonstrate proficiency in the use of mathematical methods of engineering practice
- Demonstrate proficiency in the use of a structured programming language (FORTRAN)

MODULE COURSES

COURSE CODES	COURSES
EC15MI1	Mathematics – Tensor Algebra and Analysis
EC15MI2	Programming (FORTRAN)

Module: MATHEMATICS - COMPUTER SCIENCE S5		EC15MI	ECTS: **6**
Course: MATHEMATICS – TENSOR ALGEBRA AND ANALYSIS		**EC15MI1**	Coeff.: **0,500**
LECTURERS(S): **LAURENT S., COUTURE F.**			
Lec.: **16** h	Prac.: **26** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

This module presents the essential mathematical tools to treat the majority of fundamental physical phenomena.

LEARNING OUTCOMES

-master matrix calculation,
-be able to solve analytically linear systems,
-be able to evaluate simple, double, triple, curve and surface integrals,
-be able to handle gradient, divergence and rotational,
-be able to solve analytically differential equations,
-be able to integrate, derivate spatial tensor fields,
-be able to read and understand on a mathematical point of view heat and mass transport equations.

DESCRIPTION

Part I. Matrix calculation
Matrix – Determinants – Resolution of linear systems – Matrix reduction.
Part II. Functions of several variables
Definition – Differential calculation.
Part III. Integrals calculation
Simple integrals – Double integrals – Triple integrals.
Part IV. Vector analysis
Differential operators – Curve and surface integrals – Transformation formula.
Part V. Differential equations
1st order differential equations – 2nd order linear differential equations.
Part VI. Laplace transformation
Generalised integrals – Laplace transformation of current functions – Convolution product – Dirac function.
Part VII. Tensor Algebra and Analysis
Algebra: tensor definitions and associated operations (tensor product and contracted product) in three dimensional cartesian orthogonal basis.
Analysis: integration and derivative of spatial tensor fields (vector, second order tensor and three order tensor fields), gradient, divergence, vector product, …

ASSESSMENT

CC(EE, 2h, sd, sc)

RECOMMENDED READING

Mathématiques d'usage courant pour scientifiques et ingénieurs, Belorizky E., cahiers 128, Nathan université.
HLADICK J. Le calcul vectoriel en physique, Paris, Ellipse, 1993
HLADICK J. Le calcul tensoriel en physique, Paris, Masson, 1995

PREREQUISITE

Module: MATHEMATICS - COMPUTER SCIENCE S5		EC15MI	ECTS: **6**
Course: PROGRAMMING (FORTRAN)		**EC15MI2**	Coeff.: **0,500**
LECTURERS(S): **FRANQUET E.**			
Lec.: **12** h	Prac.: h	Lab.: **20** h	Proj.: **15** h
Mandatory Course		Language : English	

OVERVIEW

Basic knowledge on computers and programming are developped. Key concepts needed to write a code dedicated to scientific computing are given.

LEARNING OUTCOMES

Masterize the basic concepts (OS commands, compilation, execution, files manipulation…)
Conceive the architecture of a program
Code a sequential program in Fortran

DESCRIPTION

1 Foreword
2 Data types
3 Operators
4 Intrinsic functions
5 Algorithms
6 Arrays
7 Sub-programs
8 Inputs – Outputs
9 Supplementary options
10 Useful information

ASSESSMENT

Proj(Tr, Rap, Sout)

RECOMMENDED READING

[1] Numerical recipes in Fortran 77 : the art of scientific computing, W.H. Press et al, Cambridge University Press (1992)
[2] Fortran 95 Handbook, A. Brainerd et al., MIT Press (1997)
[3] Information technology – Programming Languages – Fortran – Part 1 : Base language, International Standard, ISO/IEC 1539-1 (1997)
[4] Programmer en Fortran 90 – Guide Complet, C. Delannoy, Edition Eyrolles (2000) Manuel Complet du Langage Fortran 90 et 95, P. Lignelet, Masson (1996)
[5] Cours Fortran 95, P. Corde et H. Delouis, IDRIS (2008)
[6] Les apports de Fortran 2003, P. Corde et H. Delouis, IDRIS (2008)

PREREQUISITE

MODULE :

Thermodynamics – Balances S5

ECTS : 10	MODULE CODE : EC15TB

MODULE LEARNING OUTCOMES:

• Demonstrate the ability to measure enthalpy, entropy and chemical potential of pure substances and mixtures
• Demonstrate the ability to formulate and to use the first and the second law of thermodynamics with or without any chemical reaction
• Demonstrate the ability to write and to solve dynamic steady-state mass and energy balances, on units (macroscopic balance) or processes (process dynamics)
• Demonstrate the ability to implement mass and energy balances notions in pilot plants while integrating an experimental perspective: measurement uncertainty, orders of magnitude...
• Demonstrate the ability to present results in a clear and relevant way

MODULE COURSES

COURSE CODES	COURSES
EC15TB1	Introduction to Chemical Engineering
EC15TB2	General Thermodynamics
EC15TB3	Chemical Thermodynamics
EC15TB4	Heat and Mass Balances
EC15TB5	Thermo/Balance Practicals

Module: THERMODYNAMICS – BALANCES S5			EC15TB	ECTS: **10**
Course: INTRODUCTION TO CHEMICAL ENGINEERING			**EC15TB1**	Coeff.: **0,100**
LECTURERS(S): **MORY M.**				
Lec.: **10** h	Prac.: **6** h	Lab.: h	Proj.: h	
Mandatory Course		Language : French		

OVERVIEW

This course introduces the principles of chemical engineering. The concept of unit operation is illustrated by the presentation of several processes involving different classical unit operations. The principles of mass and energy balance are also given.

LEARNING OUTCOMES

The course does not aim to provide a specific knowledge but rather to indicate why and how the different courses will contribute during the next three years to provide the background for a chemical engineer. An overview of the common field between chemical engineering and energetic engineering is also given.

DESCRIPTION

•Definition and objectives of chemical/process engineering
•Example 1: oil/water emulsion, illustrated with the production of a mayonnaise, discussing the change in scale
•Example 2: chemical reaction in a reactor (chemical kinetics and thermal features)
•Notion of unit operation: mixing, reaction, separation
•Notion of time of residence
•Example 3: a process of thermodynamics separation - distillation
•Example 4: interfacial transfers illustrated by a process of gas cleaning, discussing the effect of specific area and the mass balance
•Power and energy: units and orders of magnitude
•Example 5: the production of wine
•An overview of mechanical separation processes
•A discussion of balance sheets applied to different quantities : mass, momentum, energies, finance.

ASSESSMENT

CC(EE, 1h, sd, st)

RECOMMENDED READING

Génie des procédés, ouvrage coordonné par A. Storck et G. Grevillot, Collection Tech & Doc, Lavoisier, 1993

PREREQUISITE

None

Module: THERMODYNAMICS – BALANCES S5		EC15TB	ECTS: **10**
Course: GENERAL THERMODYNAMICS		**EC15TB2**	Coeff.: **0,300**
LECTURERS(S): **SERIN J-P.**			
Lec.: **16** h	Prac.: **20** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

re(voir) les notions fondamentales de la thermodynamique nécessaires à l'ingénieur

LEARNING OUTCOMES

After the course students should:
- have some knowledge of the functions of thermodynamics
- apply the thermodynamics laws for balances of energy and entropy
- have some knowledge of the chemical or phase equilibrium laws
- have some knowledge of the phase transformations of pure substances

DESCRIPTION

To recall the main definitions in thermodynamics
Description of a thermodynamic system. Characteristics and variables of states
First and second laws of thermodynamics for multiphase systems
Differentials of the functions of states
General laws for the thermodynamical properties of solutions
Applications of Perfect gases
Thermodynamic paths and residuals functions
Phase transformations of pure substances

ASSESSMENT

CC(EE, 2h,ca)

RECOMMENDED READING

PREREQUISITE

Module: THERMODYNAMICS – BALANCES S5		EC15TB	ECTS: **10**
Course: CHEMICAL THERMODYNAMICS		**EC15TB3**	Coeff.: **0,200**
LECTURERS(S): **LAURENT S.**			
Lec.: **16** h	Prac.: **14** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The role of chemical thermodynamics is to predict if a chemical system can evolve spontaneously and how it will evolve from the calculation of two fundamental state functions: energy and entropy.

LEARNING OUTCOMES

be able to evaluate the enthalpy, the entropy and the chemical potential of components of ideal or real chemical systems,
be able to calculate standard and real reaction properties (energy, entropy, Gibbs energy, …) in function of temperature, pressure and composition of the system,
be able to evaluate energy and entropy changes in close systems where a chemical reaction takes place using 1st and 2nd principles of thermodynamics,
be able to predict the evolution of a chemical reaction and to determine the final state of the system when the equilibrium is reached.

DESCRIPTION

Part I. Introduction
State variables and functions – Chemical transformation – Reaction properties
Part II. First principle of thermodynamics
Internal energy and enthalpy – Thermochemistry
Part III. Second and third principles
Entropy – 2e principle – 3e principle – Change of entropy during a chemical reaction.
Part IV. Free enthalpy and chemical potential
Free energy – Free enthalpy – Change of free enthalpy in closed systems without chemical reaction– Chemical potential.
Part V. Chemical equilibrium
Chemical reaction progress – Variance – Displacement of a chemical equilibrium state.

ASSESSMENT

CC(EE, 2h, sd, ca)

RECOMMENDED READING

Thermodynamique chimique, Oturan M.A., Robert M., Collection Grenoble Sciences.

PREREQUISITE

EC15TB2 General thermodynamics

Module: THERMODYNAMICS – BALANCES S5		EC15TB	ECTS: **10**
Course: HEAT AND MASS BALANCES		**EC15TB4**	Coeff.: **0,100**
LECTURERS(S): **SOCHARD S.**			
Lec.: **6** h	Prac.: **12** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

This course gives some tools in order to determine mass and energy balances on different chemical units.

LEARNING OUTCOMES

After this course, students should:
-be able to write a total or partial mass balance
-be able to write a balance on each specie on every ideal reactor
-be able to write an energy balance
-be able to determine the molar enthalpy of a stream with the suitable reference
-understand flow sheets for units in the chemical and petroleum industry
-be able to make and control mass balances on these units.
-be able to make and control energy balances on these units.

DESCRIPTION

Part I : Mass Balance
1)Introduction
- **a)Definitions**
- **b)The law of conservation of mass**
- **c)Process classification**

2)How to set up Mass balances on continuous industrial units in steady state
- **a)Notation**
- **b)Characteristic quantities of a production**
- **c)Equations for a mesh without reaction, degree of freedom analysis**
- **d)Equations for mixing and splitting points, degree of freedom analysis**
- **e)Equations for a mesh with reaction**
  - **Extent of reaction method**
  - **Molecular or component balance method**
  - **Element or atomic balance method**
  - **Degree of freedom analysis**
- **f)Method for solving material balance problems**
- **g)Solving strategy**

3)Example : production of methanol
Partie II : Energy Balances
1)Introduction
2)Thermodynamics
- **a)First law**
- **b)Forms of energy**
- **c)First law in open systems**
- **d)Molar enthalpy calculations**
- **e)Reference states**

3)How to set up Energy balances on industrial units
4)Example of an energy balance without reaction : isothermal absorption
5)Example of an energy balance with reaction : production of sulphuric acid

ASSESSMENT

CC(EE, 2h, ca)

RECOMMENDED READING

Chimie industrielle. Cours et problèmes résolus, Lefrançois B., Editions Lavoisier, Technique et documentation, 1995
Bilans matière et énergétique pour l'ingénierie chimique, Ghasem, henda, Editions De Boeck, 2012
Procédés de pétrochimie. Tome 1 Gaz de synthèse et ses dérivés (Le). Les grands intermédiaires hydrocarbonés, Chauvel A., Lefebvre G., Castex L., Editions TECHNIP, 1985
Procédés de pétrochimie. Tome 2 Grands intermédiaires oxygénés, chlorés et nitrés, Chauvel A., Lefebvre G., Castex L., Editions TECHNIP, 1986
Chimie industrielle (Tomes I et II), Perrin R., Scharff J.P., Editions Masson, 1993

PREREQUISITE

Introduction to chemical engineering
General thermodynamics

Module: THERMODYNAMICS – BALANCES S5		EC15TB	ECTS: **10**
Course: THERMO/BALANCE PRACTICALS		**EC15TB5**	Coeff.: **0,300**
LECTURERS(S): **SERRA S.**			
Lec.: h	Prac.: h	Lab.: **35** h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

In the practical ENSGTI laboratory, students have the opportunity to observe, by handling on lab-scale devices, the physical phenomena they have studied during the lectures. They check the corresponding physical laws including the heat and mass transfers quantification.
This practical work corresponds to the study of the various basic physical phenomena met in the process field.

LEARNING OUTCOMES

After this course the students should :
Be familiar with the main physical phenomena encountered in thermodynamic;
Be able to analyse a real experiment (measurement uncertainties, order of magnitude);
Know how to present clearly scientific relevant results.

DESCRIPTION

- Data analysis
- Critical point determination
- Distillations
- Evaporation
- Tubular heat exchanger
- Cooling tower
(- Gas Phase Chromatography)

ASSESSMENT

moyenne(TP(CR))x1/2 + moyenne(TP(Tr, PA))x1/2

RECOMMENDED READING

PREREQUISITE

MODULE :

Transport Phenomena – Mechanics S5

ECTS : 10	MODULE CODE : EC15TM

MODULE LEARNING OUTCOMES:

• Understand the basic laws of transport phenomena (Fick's laws, Fourier's laws and Newton's laws) along with radiation
• Demonstrate the ability to formulate, on the microscopic scale, mass, energy and momentum balances and to know how to solve them, in simple cases
• Know the main dimensionless numbers
• Understand the basic knowledge in fluid mechanics on pilot plants while integrating an experimental perspective: measurement uncertainty, orders of magnitude...
• Demonstrate the ability to present results in a clear and relevant way

MODULE COURSES

COURSE CODES	COURSES
EC15TM1	Introduction to Transport Phenomena
EC15TM2	Heat Conduction I
EC15TM3	Diffusion
EC15TM4	Heat Transfer by Radiation
EC15TM5	Continuum Mechanics
EC15TM6	Transfer Practicals

Module: TRANSPORT PHENOMENA – MECHANICS S5		EC15TM	ECTS: **10**
Course: INTRODUCTION TO TRANSPORT PHENOMENA		**EC15TM1**	Coeff.: **0,100**
LECTURERS(S): **MARIAS F.**			
Lec.: **6** h	Prac.: **4** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

Momentum, heat and mass transport phenomena can be found nearly everywhere in nature. During the designing of an industrial process plant, quantitative considerations play a major role. The experience that mass, energy and momentum cannot be lost provides the three conservation laws, on which the quantitative analysis of physical and chemical process totally relies and on which the process design of a plant is based. These conservation laws provide the background for process designs. However, they do not yield any information on how these quantities are transported inside a specific device. Thus it is also required to describe these phenomens in order to have complete knowledge in this field.

LEARNING OUTCOMES

After this course, students should:
-be able to write mass and energy balance on macroscopic and simple systems
-know the three laws for molecular transport
-know the expression of the main dimensionless number

DESCRIPTION

Part I: Conservation laws
The three conservations laws are derived in this first part. Their integral formulation is given for any system and examples of their application are given :
Part II: Molecular transport
-Mass (Fick's first Law)
-Heat (Fourier's Law),
-Momentum (Newton's Law)
Part III: Dimensionless numbers
-Prandtl's number
-Scmidt's number
-Lewis' number

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

Bird Stewart Lightfoot, Transport Phenomena 2nd Edition, Wiley, 2002
Beek & Muttzall, Transport Phenomena, Wiley, 1975

PREREQUISITE

General Mathematics
System of coordinates
- Cartesian
- Polar
- Spherical

Module: TRANSPORT PHENOMENA – MECHANICS S5		EC15TM	ECTS: **10**
Course: HEAT CONDUCTION I		**EC15TM2**	Coeff.: **0,100**
LECTURERS(S): **BERNADA P., BEDECARRATS J-P.**			
Lec.: **10** h	Prac.: **10** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The aim is to give the students the fundamental basis of heat transport by conduction and thermal science.

LEARNING OUTCOMES

After this course, students should be able to:
-Write properly the heat conduction equation for several geometrical cases, Fourier's law and perfect contact conditions between two solids,
-Solve the heat conduction equation in solids, in simple steady state and transient cases,
-Calculate the heat flux transferred from a solid to a fluid or another solid.

DESCRIPTION

I Heat transport in non deformable bodies
•Definition of the contact heat flux, Fourier's law, thermal conductivity
•Conservation of energy equation, transient and steady conduction,
•Implications of the Clausius-Duhem inequality
II Heat transfer by contact between two solid bodies
•Study of the contact conditions between two solids
III Energy balances on macroscopic systems
•Detailed method to obtain rigorous macroscopic balance equations, by integration of microscopic conservation equations over specified bodies,
•Comparison with more simple and intuitive methods
IV. Fundamental concepts and general equations of conduction
•General information, definitions
•Equations of heat for an homogeneous and isotropic medium
•Boundary conditions space-time
•Steady state. Thermal resistances. Fins.
•Non steady state. Biot criterion.

ASSESSMENT

CC(EE, 2h, sd, ca)

RECOMMENDED READING

-Advanced transport phenomena, J.C. Slattery, Cambridge Press, 1999
-Transport phenomena, Bird, Stewart and Lightfoot, John Wiley and Sons, 1960
-Fundamental principles of heat transfer, WHITAKER Stephen. KRIEGER, 1977

PREREQUISITE

Continuum Mechanics (EC15TM5)
Thermodynamics (EC15TB2)

Module: TRANSPORT PHENOMENA – MECHANICS S5		EC15TM	ECTS: **10**
Course: DIFFUSION		**EC15TM3**	Coeff.: **0,100**
LECTURERS(S): **BERNADA P.**			
Lec.: **4** h	Prac.: **6** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

In this course, the fundamental basis of mixing theory and diffusion are presented to the students.

LEARNING OUTCOMES

After this course, students should be able to:
-Write properly the diffusion equation for several geometrical cases, and mass transfer boundary conditions between two multicomponent continua,
-Solve the diffusion equation, in simple steady state and transient cases,
-Use Fick's law in order to calculate the diffusive flux in a binary fluid.

DESCRIPTION

II Basis of diffusion transport
•Definition of the diffusive flux, Fick's law, diffusive coefficient
II Generalities on mixing theory in continua
•The body species concept
•Conservation equation of mass, momentum and energy for one component
•Conservation equation of mass, momentum and energy for the mixture
•Simplification of the model : the link with Fick's law, equation of diffusion
III Mass transfer between two multicomponent continua

ASSESSMENT

CC(EE, 2h, da:cours, ca)

RECOMMENDED READING

Advanced transport phenomena, J.C. Slattery, Cambridge Press, 1999
Transport phenomena, Bird, Stewart and Lightfoot, John Wiley and Sons, 1960

PREREQUISITE

Continuum mechanics (EC1TM5)

Module: TRANSPORT PHENOMENA – MECHANICS S5	EC15TM	ECTS: **10**
Course: HEAT TRANSFER BY RADIATION	**EC15TM4**	Coeff.: **0,100**
LECTURERS(S): **VAXELAIRE J.**		

Lec.: **6** h	Prac.: **14** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

Heat transfer by radiation is of high importance especially in systems where high temperature is involved. The goal of the lecture is to present the basic elements on this particular heat transfer phenomena.

LEARNING OUTCOMES

After this course, students should:
-have a basic knowledge on radiation phenomena
-be able to include aspects relative to radiation in relatively simple thermal systems

DESCRIPTION

Definitions and fundamental relationships (radiant intensity and flux…)
Black body radiation (black body definition; spectral energy distribution, fractional functions)

Real surfaces radiation (absorption and emission characteristics, gray surfaces, Kirchhoff law)
Heat exchange between black surfaces separated by nonabsorbing medium (geometry factor, electrical analogy)
Heat exchange between gray surfaces separated by nonabsorbing medium
Heat exchange between surfaces separated by partially absorbing medium (particular case of isothermal gas)

ASSESSMENT

CC(EE,1h, sd,ca)x1/2 + CC(EE,1h, sd,ca)x1/2

RECOMMENDED READING

BEJAN A. "heat transfer", Ed. J. Wiley, 1993, New York
BATTAGLIA J.L. et al. "Introduction aux transferts thermiques", Ed. Dunod, 2014, Paris
SACADURA J.F "Initiation aux transferts thermiques", Ed. Lavoisier, 1978, Paris

PREREQUISITE

Module: TRANSPORT PHENOMENA – MECHANICS S5	EC15TM	ECTS: **10**
Course: CONTINUUM MECHANICS	**EC15TM5**	Coeff.: **0,300**
LECTURERS(S): **COUTURE F.**		

Lec.: **20** h	Prac.: **16** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

Continuum mechanics is the theoretical basis for fluid and solid mechanics.
The aim is to describe transport phenomena in continuum from the classical universal principles : mass, momentum and energy conservation

LEARNING OUTCOMES

After this course, students should:
-be able to establish the basic equations of fluid mechanics (Bernoulli, Navier Stokes) by introducing a newtonian rheological behaviour in mass and momentum conservation,
-be able to establish the basic equations of thermal science by introducing a Newtonian rheological behaviour for fluid and a non deformable behaviour for solid in energy conservation.

DESCRIPTION

Continuum model :
Averaging volume – Continuity of the medium at a given time - Continuity of transformations.
Kinematics:
Lagrangian method – Eulerian method – Material derivative – Transport theorem – Conservation of mass.
Dynamics:
Forces – Momentum and moment of momentum balances – Stress tensor – Symmetry of stress tensor – Energy conservation.
Rheology - Stress-strain relations
Strain tensor – Rate of strain tensor - – Tensors properties – Stress strain relations (Newtonian fluid, linear elastic solid).

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

DUVAUT G., Mécanique des milieux continus, Paris, Masson, 1990
BOUDET R., CHAUVIN A., Mécanique des milieux continus, Paris, Hermes, 1996

PREREQUISITE

Module: TRANSPORT PHENOMENA – MECHANICS S5		EC15TM	ECTS: **10**
Course: TRANSFER PRACTICALS		**EC15TM6**	Coeff.: **0,300**
LECTURERS(S): **SERRA S.**			
Lec.: h	Prac.: h	Lab.: **40** h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

In the practical ENSGTI laboratory, students have the opportunity to observe, by handling on lab-scale devices, the physical phenomena they have studied during the lectures. They check the corresponding physical laws including the heat and mass transfers quantification.
This practical work corresponds to the study of the various basic physical phenomena met in the energy field.

LEARNING OUTCOMES

After this course the students should :
Be familiar with the main physical phenomena encountered in thermal and energetic systems;
Be able to analyse a real experiment (measurement uncertainties, order of magnitude);
Know how to present clearly scientific relevant results.

DESCRIPTION

- Rheology
- pressure losses
- Centrifuge pump
- Conduction
- Convection
- Radiation
- Temperature measurement

ASSESSMENT

moyenne(TP(CR))x1/2 + moyenne(TP(Tr, PA))x1/2

RECOMMENDED READING

PREREQUISITE

SEMESTER 6

SEMESTER MODULES

COMMON COURSE or ELECTIVE	MODULE CODES	MODULE TITLES	ECTS
Com. Course	EC16LC	Languages - Engineering Culture S6	6
Com. Course	EC16MI	Mathematics - Computer Sciences S6	6
Com. Course	EC16TM	Thermodynamics - Mechanics S6	8
Energ.	EE16CC	Control S6	6
Energ.	EE16MT	Materials and transfers S6	4
Proc. Eng.	EP16CH	Chemistry S6	6
Proc. Eng.	EP16RE	Reactor S6	4

MODULE :

Languages - Engineering Culture S6

ECTS : 6		MODULE CODE : EC16LC

MODULE LEARNING OUTCOMES:

- Demonstrate the ability to communicate in English (B2 Level)
- Demonstrate the basic knowledge of a second language
- Know the professional environment and understand the business organisation
- Understand the basics of management control system and cost analysis
- Understand the basics of entrepreneurship

MODULE COURSES

COURSE CODES	COURSES
EC16LC1	English
EC16LC2	Second Foreign Language (Spanish)
EC16LC2	Second Foreign Language (German)
EC16LC3	Professional Insertion I
EC16LC4	Entrepreneurship
EC16LC5	Cost Analysis and Management Control

Module: LANGUAGES - ENGINEERING CULTURE S6		EC16LC	ECTS: **6**
Course: ENGLISH		**EC16LC1**	Coeff.: **0,333**
LECTURERS(S): **DELAMBRE Y.**			
Lec.: h	Prac.: **24** h	Lab.: h	Proj.: h
Mandatory Course		Language : English	

OVERVIEW

The focus of this class is to strenghten the English skills to successfully pass the official TOEIC (Listening and Reading) Test of English for International Communication.
The TOEIC is correlated to the Common European Framework of Reference for Languages (CEFR).

LEARNING OUTCOMES

The student masters the technical skills required for the TOEIC test and gains confidence to improve his/her final score. The student can communicate in everyday workplace situations in a professional environment.

DESCRIPTION

The course is based on Business English and covers vocabulary and grammar useful for the business environment. Oral expression.
Specific intensive training for the TOEIC test as well as mock exams.

ASSESSMENT

Cert(TOEIC 1)x2/10 + Cert(TOEIC 2)x4/10 + ExEx2/10 + ExOx2/10

RECOMMENDED READING

Pearson: Preparation for the New Toeic Test and Market Leader
Macmillon: Business grammar Builder and Business Vocabulary Builder

PREREQUISITE

Level intermediate to advanced (A1 to C2)

Module: LANGUAGES - ENGINEERING CULTURE S6	EC16LC	ECTS: **6**
Course: SECOND FOREIGN LANGUAGE (SPANISH)	**EC16LC2**	Coeff.: **0,167**
LECTURERS(S): **ARMENTA A., COBOS A., NOËLL N.**		

Lec.: h	Prac.: **20** h	Lab.: h	Proj.: h
Mandatory Course		Language : Spanish	

OVERVIEW

El objetivo es mejorar y consolidar las diferentes competencias definidas por el Marco común europeo de referencia para las lenguas.

LEARNING OUTCOMES

Nivel A1 o Acceso : Es capaz de comprender y utilizar expresiones cotidianas de uso muy frecuente así como frases sencillas destinadas a satisfacer necesidades de tipo inmediato. Puede presentarse a sí mismo y a otros, pedir y dar información personal básica sobre su domicilio, sus pertenencias y las personas que conoce. Puede relacionarse de forma elemental siempre que su interlocutor hable despacio y con claridad y esté dispuesto a cooperar.
Nivel A2 o Plataforma: Es capaz de comprender frases y expresiones de uso frecuente relacionadas con áreas de experiencia que le son especialmente relevantes (información básica sobre sí mismo y su familia, compras, lugares de interés, ocupaciones, etc). Sabe comunicarse a la hora de llevar a cabo tareas simples y cotidianas que no requieran más que intercambios sencillos y directos de información sobre cuestiones que le son conocidas o habituales. Sabe describir en términos sencillos aspectos de su pasado y su entorno así como cuestiones relacionadas con sus necesidades inmediatas.
Nivel B1 o Intermedio: Es capaz de comprender los puntos principales de textos claros y en lengua estándar si tratan sobre cuestiones que le son conocidas, ya sea en situaciones de trabajo, de estudio o de ocio. Sabe desenvolverse en la mayor parte de las situaciones que pueden surgir durante un viaje por zonas donde se utiliza la lengua. Es capaz de producir textos sencillos y coherentes sobre temas que le son familiares o en los que tiene un interés personal. Puede describir experiencias, acontecimientos, deseos y aspiraciones, así como justificar brevemente sus opiniones o explicar sus planes.
Nivel B2 o Intermedio alto:
Es capaz de entender las ideas principales de textos complejos que traten de temas tanto concretos como abstractos, incluso si son de carácter técnico siempre que estén dentro de su campo de especialización. Puede relacionarse con hablantes nativos con un grado suficiente de fluidez y naturalidad de modo que la comunicación se realice sin esfuerzo por parte de ninguno de los interlocutores. Puede producir textos claros y detallados sobre temas diversos así como defender un punto de vista sobre temas generales indicando los pros y los contras de las distintas opciones.
Nivel C1 o Dominio operative eficaz: Es capaz de comprender una amplia variedad de textos extensos y con cierto nivel de exigencia, así como reconocer en ellos sentidos implícitos. Sabe expresarse de forma fluida y espontánea sin muestras muy evidentes de esfuerzo para encontrar la expresión adecuada. Puede hacer un uso flexible y efectivo del idioma para fines sociales, académicos y profesionales. Puede producir textos claros, bien estructurados y detallados sobre temas de cierta complejidad, mostrando un uso correcto de los mecanismos de organización, articulación y cohesión del texto.

DESCRIPTION

Variable en función del nivel.
Documentos auténticos de la vida cotidiana y de especialidad.
Documentos audio y video con trabajo de comprensión oral acompañdos de parrillas de comprensión.
Comunicación interna y externa. Interculturalidad.
Escritos profesionales (carta de presentación, CV, noticias, correos, documentos técnicos, informes…)
Trabajo en la red: www.ver-taal.com comprensión oral de reportajes, fragmentos de informaciones televisivas, enriquecimiento del vocabulario
Búsquedas sobre España y América Latina
Búsquedas sobre empresas españolas y latinoamericanas.

ASSESSMENT

CoOx1/5 + ExOx1/5 + IntOx1/5 + CoEx1/5 + ExEx1/5

RECOMMENDED READING

Documentos proporcionados por las profesoras en función del nivel.
Mundo laboral :http://www.oficinaempleo.com/content/manualcv1.html
TV : http://www.rtve.es/
Prensa: http://elpais.com/
Español : www.ver-taal.com
Plateforma Chamilo de l'UPPA.

PREREQUISITE

Ninguno para el grupo 1, nivel A2:B1 para el grupo 2, nivel B1/B2 para el grupo 3

Module: LANGUAGES - ENGINEERING CULTURE S6		EC16LC	ECTS: **6**
Course: SECOND FOREIGN LANGUAGE (GERMAN)		**EC16LC2**	Coeff.: **0,167**
LECTURERS(S): **PLÖGER S.**			
Lec.: h	Prac.: **20** h	Lab.: h	Proj.: h
Mandatory Course		Language : German	

OVERVIEW

LEARNING OUTCOMES

Einen Lebenslauf und ein Bewerbungsschreiben verfassen, sich Information über Jobangebote und Wohnungsmöglichkeiten verschaffen, an einem Gespräch über allgemeine Themen teilnehmen

DESCRIPTION

Grammatische Wiederholungen der wichtigsten Strukturen, spezifischer Wortschatz (Job – und Wohnungssuche), allgemeiner Wortschatz, Lese-und Hörverständnis (Artikel, Video..)

ASSESSMENT

CoOx1/5 + ExOx1/5 + IntOx1/5 + CoEx1/5 + ExEx1/5

RECOMMENDED READING

Site internet de la Deutsche Welle : www.fluter.de

PREREQUISITE

5 Jahre Deutsch (9. bis 13. Klasse)

Module: LANGUAGES - ENGINEERING CULTURE S6	EC16LC	ECTS: **6**
Course: PROFESSIONAL INSERTION I	**EC16LC3**	Coeff.: **0,167**
LECTURERS(S): **MERCADIER J.**		

Lec.: **4** h	Prac.: **2** h	Lab.: h	Proj.: **14** h
Mandatory Course		Language : French	

OVERVIEW

The purpose of this project is to lead each student to think about his/her career. Thereafter he/she can chose training periods, projects, optional courses, international experiences during the second and third year according to his/her need,

LEARNING OUTCOMES

Students will be able to search any informations necessary for job hunting;

DESCRIPTION

Rules for the oral presentation and file content.
-Functions
-Industries
-Opportunities
-Interest of training
-Knowing the companies

ASSESSMENT

Proj(Rap, Sout)

RECOMMENDED READING

www.apec.fr
www.kompass.fr
www.onisep.fr
www.pole-emploi.fr
www.observatoireindustrieschimiques.com

PREREQUISITE

None

Module: Languages - Engineering Culture S6		EC16LC	ECTS: **6**
Course: ENTREPRENEURSHIP		**EC16LC4**	Coeff.: **0,167**
Lecturers(s): **Collet Gaignard A.**			
Lec.: **12** h	Prac.: h	Lab.: h	Proj.: **10** h
Mandatory Course		Language : French	

OVERVIEW

This course's goal is to give the students the necessary basis to create activities (such as managing enterprises projects, creation of an enterprise) thanks to a theoretical content which permits to ask appropriate questions for a successfull project while letting enough time to put it inot practice. It belongs to the PEPITE program (Pôles Etudiants Pour l'Innovation, le Transfert et l'Entreprenariat) launched by the Ministry of National Education, of Higher Education and Research, which is developped, at a regional level, by Entreprenariat Campus Aquitaine (ECA). This course allowsthe students who want to continue their creative practice to go into an appropriate further training (Student-Entrepreneur University degree or D2E) with an individual support.

LEARNING OUTCOMES

- Master the GRP Lab
- Present your business model in front of a jury
- Work efficiently in groups in order to complete the project
- Master the basic entrepreneurship notions

DESCRIPTION

The theoretical content is organised in 4 main topics :
- notion of market
- the business model
- the financial terms
- legal forms and personal status
The Tools
- students have access to the GRP Story Teller which enables them to organize their reflections and propose a presentable version of their project to the shareholders. Students have also access to GRP Lab where they can find documents, records and further information.
Application
Students, organised in groups, will have to work together on a fictional enterprise project (or not). They will present their business model in front of a jury made of teachers and professionals specializing in business creation.

ASSESSMENT

Proj(Sout)

RECOMMENDED READING

•Verstraete Thierry (dir), Histoire d'entreprendre- les réalités de l'entrepreneuriat, Edition Management et Société, 2000.
•Fayolle Alain, Introduction à l'entrepreneuriat, Dunod, collection Topos, 2011.

PREREQUISITE

Module: LANGUAGES - ENGINEERING CULTURE S6		EC16LC	ECTS: **6**
Course: COST ANALYSIS AND MANAGEMENT CONTROL		**EC16LC5**	Coeff.: **0,167**
LECTURERS(S): **LEMAN V.**			
Lec.: **20** h	Prac.: h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

Cost analysis is a part of management, but requires knowledge of production processes.

LEARNING OUTCOMES

-understand different methods of cost analysis
-be able to choose the appropriate one to help decision-making
-draw up budgets, calculate and analyse the gaps between realizations and budget estimates to correct decisions if necessary

DESCRIPTION

PART I- COST ANALYSIS
Cost analysis by product, activity, function or project...
-full-cost analysis
-direct costing analysis
-cost-volume-profit
PART II- MANAGEMENT CONTROL
-budgets by function
-performance control
-reporting panel

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

“Contrôle de gestion, DCG 11, manuel et applications” by Claude ALAZARD and Sabine SEPARI, éditions Expert Sup DUNOD, 2013

PREREQUISITE

Accountancy

MODULE :

Mathematics - Computer Sciences S6

ECTS : 6		MODULE CODE : EC16MI

MODULE LEARNING OUTCOMES:

• Understand the basic concepts of Applied mathematics (numerical mathematical methods), Statistics and Probability
• Demonstrate the ability to design and configure a control loop
• Demonstrate proficiency in the use of a new structured programming language (Visual Basic)

MODULE COURSES

COURSE CODES	COURSES
EC16MI1	Probability and Statistics
EC16MI2	Scientific Calculus I
EC16MI3	System Control
EC16MI4	Programming (VBA)

Module: MATHEMATICS - COMPUTER SCIENCES S6		EC16MI	ECTS: **6**
Course: PROBABILITY AND STATISTICS		**EC16MI1**	Coeff.: **0,167**
LECTURERS(S): **LUCE R.**			
Lec.: **10** h	Prac.: **10** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

This course will concentrate on probability theories and statistical methods. To understand and model random phenomenon is of prime importance for a lot of complex situations where the classical deterministic methods do not fit well. Special attention is paid in this course to real-life problems.

LEARNING OUTCOMES

After this course, students should

- **have a basic knowledge in the area of probabilities,**
- **be able to model a random phenomenon,**
- **have a basic knowledge in the aera of statistics**
- **be able to fit a linear statistical model**

DESCRIPTION

3 parts
Part I : Probabilities
Part II : Inferential statistics
Part III: Statistical linear models

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

G. Sapora, Probabilités, Analyse des données et Statistique. Edition Technip 2006
Murray R. Spiegel, Probabilité et Statistique, Série SCHAUM, 1974

PREREQUISITE

- **Enumerative combinatorics**
- **Concept of probability and conditional probobility**
- **Random variables notions and probability distribution**

Module: MATHEMATICS - COMPUTER SCIENCES S6		EC16MI	ECTS: **6**
Course: SCIENTIFIC CALCULUS I		**EC16MI2**	Coeff.: **0,333**
LECTURERS(S): **GIBOUT S.**			
Lec.: **14** h	Prac.: **16** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The main objective of this module is to provide students with a solid foundation in scientific computing, which allows them to use the computer in the modeling framework and data analysis.

LEARNING OUTCOMES

Choose the most suitable algorithms for a given problem and implement them in the computer language of their choice
Take a critical look at results
Evaluate any errors related to the method

DESCRIPTION

1. Solution of linear systems
2. Interpolation and approximation techniques
3. Integration and numerical derivation
4. Nonlinear Equations
5. Extremums and minimization
6. Resolution of systems of ordinary differential equations

ASSESSMENT

CC(EE,sd,st,ca,1h)x1/4 + CC(EE,sd, st, ca, 2h)x3/4

RECOMMENDED READING

PREREQUISITE

Basic skills in Mathematics and programming

Module: MATHEMATICS - COMPUTER SCIENCES S6		EC16MI	ECTS: **6**
Course: SYSTEM CONTROL		**EC16MI3**	Coeff.: **0,333**
LECTURERS(S): **BERNADA P.**			
Lec.: **12** h	Prac.: **12** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

This lecture is an introduction to PID process control and system instrumentation.

LEARNING OUTCOMES

After this course, students should be able to:
-Give the elements of a control loop,
-Calculate the time response of simple systems (first and second order) placed in feedback control loops with PID controllers,
-Choose an appropriate controller for simple processes (pressure, level, flow rate…)
-Improve the process control by using simple criteria

DESCRIPTION

I Introduction
Brief description of the elements of a control loop (sensor, actuators, controllers)
II Mathematical modeling of dynamic linear systems
•Definition of a transfer function,
•Study of simple linear systems (first order, second order, integrator, dead time…)
III Basic control actions
•Closed loop systems (feedback systems),
•PID controllers,
IV Stability of linear systems
•Routh criterion,
•Root locus diagram
V Optimization of a PID controller
•Static and dynamic criteria,
•Choice of the controller,
•Optimization of a PID (Ziegler – Nichols, Cohen and Coon)

ASSESSMENT

CC (EE, 2h, da : notes de cours, ca)

RECOMMENDED READING

Modern control engineering, 2d edition, prentice-hall edition, K Ogata, 1990
Regulation, tomes 1,2,3, Nathan edition, C. Sermonade, A. Toussaint, 1994

PREREQUISITE

Maths - tensorial algebra and analysis (EC15MI1)

Module: MATHEMATICS - COMPUTER SCIENCES S6		EC16MI	ECTS: **6**
Course: PROGRAMMING (VBA)		**EC16MI4**	Coeff.: **0,167**
LECTURERS(S): **GIBOUT S.**			
Lec.: **8** h	Prac.: **12** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

Mastering VBA / Excel

LEARNING OUTCOMES

Analyze a problem and design the most suitable software solution
Develop the application following a methodology to minimize the risk of error (tests)
Validate and correct any nonconformities
Take account of ergonomic constraints related to the use of graphical user interfaces

DESCRIPTION

1) Generalities
2) Development and execution environments
3) Object and event programming concepts
4) Data types and elements of language syntax
5) Interaction with Spreadsheets
6) Graphical User Interface

ASSESSMENT

Proj(Rap, Prog)

RECOMMENDED READING

PREREQUISITE

General principles of programming (Fortran or other)

MODULE :

Thermodynamics - Mechanics S6

ECTS : 8		MODULE CODE : EC16TM

MODULE LEARNING OUTCOMES:

• Demonstrate the ability to compute the equilibrium between phases
• Know the main unit operations so as to be able to understand and to design a process flow diagram
• Demonstrate the ability to formulate and to solve a process simulation problem with a commercial process simulation software
• Demonstrate the ability to formulate and to solve a problem in Fluid Mechanics in order to calculate pressure drop

MODULE COURSES

COURSE CODES	COURSES
EC16TM1	Solution Thermodynamics
EC16TM2	Flowsheeting
EC16TM3	PID
EC16TM4	Fluid Mechanics I

Module: THERMODYNAMICS - MECHANICS S6		EC16TM	ECTS: **8**
Course: SOLUTION THERMODYNAMICS		**EC16TM1**	Coeff.: **0,250**
LECTURERS(S): **CEZAC P.**			
Lec.: **18** h	Prac.: **16** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The thermodynamics of the solutions is an essential tool for the analysis of the real processes. The primary aim of this subject is to provide a comprehensive exposition on the thermodynamic properties of fluid mixtures and on phases equilibria

LEARNING OUTCOMES

After this course, students should:
-have a great knowledge on thermodynamics models (ideal gas, ideal solution, gE models and Equations of state)
-be able to describe any thermodynamic equilibrium in a complex system.

DESCRIPTION

- **Partial Properties**
- **Chemical Potential**
- **Ideal Gas**
- **Ideal Solution**
- **Real Solution**
- **gE models**
- **EOS**
- **Phases equilibria**

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

J. Vidal, Thermodynamique : application au Génie Chimique et à l'industrie pétrolière, Ed. Technip, 1997.
Smith et Van Ness, Introduction to Chemical Engineering Thermodynamics, Ed. Mc Graw-Hill, Inc, 1987

PREREQUISITE

Lectures of general thermodynamics and thermo chemistry

Module: THERMODYNAMICS - MECHANICS S6		EC16TM	ECTS: 8
Course: FLOWSHEETING		EC16TM2	Coeff.: 0,250
LECTURERS(S): **RENEAUME J-M.**			
Lec.: **8** h	Prac.: **16** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

This subject is dedicated to steady state process simulation. Basic concepts are first introduced. Then illustrative examples are considered using a Steady State Process Simulator (ProSim Plus ®).

LEARNING OUTCOMES

-be able to formulate simulation problems (process modelling at the system level)
-have a basic and theoretical knowledge of different solution strategies (modular, oriented equation) and methods (Wegstein, Broyden…)
-be able to use any commercial software for steady state process simulation
-be able to analyse the results of simulation (sensitivity analysis …)

DESCRIPTION

Part I: Basic Concepts
-Introduction: process classification, from design to simulation
-Model classification and formulation
-Different solution strategy (Oriented Equation, Modular …)
-The Modular Solution Strategy (Module Definition, Tear Streams, Recycle, Specification …)
-Numerical Methods
Part II: Simulation Tools
Process simulations are performed using the ProSim Plus® steady state process simulator: Simplified HDA Process, Ethylene Oxide process…

ASSESSMENT

CC(EM, 2h)

RECOMMENDED READING

Tutorials are available, on line, using the elearn platform

PREREQUISITE

Balances EC15TB4
Solution Thermodynamics EC16TM1

Module: THERMODYNAMICS - MECHANICS S6		EC16TM	ECTS: 8
Course: PID		EC16TM3	Coeff.: **0,125**
LECTURERS(S): **RICARDE M.**			
Lec.: **4** h	Prac.: **4** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

Piping and instrumentation Diagrams occupy animportant role in the industrial units of oil&gas, chemistry and energy.
The knowledge of these Diagrams is essential for an engineer in Process engineering or in Energetics.
This teaching is illustrated with concrete industrial examples; numerous notions are approached, relative to safety, technology, construction and to the exploitation of units.
Educational platform https://elearn.univ-pau.fr/

LEARNING OUTCOMES

The skills which will be acquired by the student face to face P&ID are:
1 - Reading
2 - Understanding
3 - Designing
4 - Drawing (Note: the use of software of drawing is not included in this course).

DESCRIPTION

Piping and equipment:
-outline,
-piping class.
Instrumentation:
-outline,
-identification (rules for name tag),
-sort : temperature, flow….
-function : alarm, control, security…
OTHER NOTIONS:
-Process Control Systems (PCS) ET Safety Shutdown System (SSS)
-Safety Integrity Level (SIL)
-EXPLOSIVE ATMOSPHERES (ATEX)
-NFC and NFO valves

ASSESSMENT

CC(EE, 1h)

RECOMMENDED READING

ISO 10628-1:2014 Diagrams for the chemical and petrochemical industry -- Part 1: Specification of diagrams

ISO 10628-2:2012 Diagrams for the chemical and petrochemical industry -- Part 2: Graphical symbols
ISO 14617-6:2002 Symboles graphiques pour schémas -- Partie 6: Fonctions de mesurage et de contrôle
ISA 5.1-2009 Instrumentation Symbols and Identification

PREREQUISITE

purposeless

Module: THERMODYNAMICS - MECHANICS S6		EC16TM	ECTS: 8
Course: FLUID MECHANICS I		EC16TM4	Coeff.: 0,375
LECTURERS(S): LAURENT S.			
Lec.: 20 h	Prac.: 16 h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The presence of a fluid flowing through pipes and pumps is quasi systematic in process engineering and energetic applications. Fluid mechanics allows the characterisation of fluid flows (determination of velocity, pressure, head losses…) by applying the classical universal principles.

LEARNING OUTCOMES

-be able to formulate a fluid mechanics problem by writing mass, momentum and energy conservation,
-be able to determine velocity and pressure profiles of a flowing fluid by solving the previous equations in some simple cases
(steady flow of a perfect fluid, laminar steady flow of an incompressible viscous fluid),
-be able to calculate head loss and to design pumps,
-be able to evaluate the force laid by a fluid (static or flowing) on a solid wall.

DESCRIPTION

Part I. Call back of continuum mechanics basis
Mass, momentum and energy conservation.
Part II. Definition and properties of a fluid
Rheological behaviour – Viscosity – Compressibility.
Part III. Fluid statics
Hydrostatic law – Archimede theorem – Isothermal and polytropic atmospheres.
Part IV. Fluid dynamics
Euler equations - Bernoulli theorems - Navier-Stokes equations - Laminar flows – Momentum theorem - First principle of thermodynamics applied to a fluid.
Part V. Permanent flow of an incompressible viscous fluid in a pipe
Head and pressure loss – Pumps and turbines.
Part VI. Permanent flow of a compressible perfect fluid in a variable section pipe
Saint-Venant theorem-Hugoniot theorems – Isentropic flows laws – Tuyeres.

ASSESSMENT

CC(EE, 2h, sd, ca)

RECOMMENDED READING

Mécanique expérimentale des fluides, tomes 1 et 2, R. Comolet, 5e édition Masson.
Mécanique des fluides - éléments d'un premier parcours, P. Chassaing, Cepadues éditions, Collection Polytech.

Mécanique des fluides appliquée, R. Joulié, Ellipses.
Mémento des pertes de charge, I.E. Idel'Cik, Eyrolles.

PREREQUISITE

EC15TM5 Continuum mechanics

MODULE : Control S6		
ECTS : 6		MODULE CODE : EE16CC

MODULE LEARNING OUTCOMES:

• Understand both fundamental and technological aspects of instrumentation and metrology, encountered in thermal and energy engineering
• Control the selection and the use of actuators encountered in the speciality
• Understand the principles of advanced process control, control engineering, distributed control system and system identification encountered in the speciality
• Understand the basics of electric power industry
• Know the methods for the risk assessment related to the speciality

MODULE COURSES

COURSE CODES	COURSES
EE16CC1	Identification and Advanced Command
EE16CC2	Security
EE16CC3	Industrial Electricity
EE16CC4	Automation and Instrumentation

Module: CONTROL S6		EE16CC	ECTS: **6**
Course: IDENTIFICATION AND ADVANCED COMMAND		**EE16CC1**	Coeff.: **0,167**
LECTURERS(S): **CHAMPIER D.**			
Lec.: **4** h	Prac.: **8** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The main objective is to give to the students the knowledge about identification and control of dynamic systems by using numerical tools..

LEARNING OUTCOMES

After this course the students should:
Know how to identify process and tune PID controller
Matlab and Simulink to simulate, and analyze the response of dynamic systems.
Have basic knowledge of advanced control which allows discussions with control engineers.
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DESCRIPTION

1)Continuous-time model identification
2)Tuning PID controller
3)Simulation and Model-Based Design for dynamic systems

ASSESSMENT

CC(EE, 1h, da : notes de cours, ca)

RECOMMENDED READING

Régulation P.I.D. : analogique - numérique – floue, Daniel Lequesne, Hermes Science
Feedback Control of Dynamic Systems ,Gene F. Franklin, J. Da Powell,Abbas Emami-Naeini
Matlab/Simulink pour l'analyse et la commande de systemes, Yassine HADDAB, techniques de l'ingénieur.

PREREQUISITE

Dynamic systems and control

Module: CONTROL S6			EE16CC	ECTS: **6**
Course: SECURITY			**EE16CC2**	Coeff.: **0,333**
LECTURERS(S): **CONTAMINE F.**				
Lec.: **10** h	Prac.: **10** h	Lab.: h	Proj.: h	
Mandatory Course		Language : French		

OVERVIEW

The objective of this course is to make students aware of safety. Having defined the notions of danger, risk, and gravity, this course approaches some statutory aspects. An inventory of fixtures obtained from a data bank of accidentology (BARPI) is then of use as introduction to the identification and to the evaluation of the chemical risks, then to the characterization of the effects due to the exposure in a poison gas (Lois de Haber), and finally, the evaluation of fire risks.

LEARNING OUTCOMES

Notions of danger, risk
Be aware of the main dangers
Being capable of estimating the chemical risks, and of fire by using a method simplified by analysis of the risks

DESCRIPTION

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

PREREQUISITE

none

Module: CONTROL S6	EE16CC	ECTS: **6**
Course: INDUSTRIAL ELECTRICITY	**EE16CC3**	Coeff.: **0,167**
LECTURERS(S): **SUBILEAU R.**		

Lec.: **8** h	Prac.: **6** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

Nowadays, electrical energy is essential for the effective operation of industrial enterprises. The purpose of this course is giving the students some theoretical basis to understand electrical energy from its production to its use and make them aware of electrical risks.

LEARNING OUTCOMES

Know electrical risks
Know electrical energy distribution principles
Know electronical conversion principles
Be able to perform a first analysis of an electrical machine

DESCRIPTION

1 Main industrial electricity principles
2 Electrical risks sensitivity
3 Three phase grids
4 Electronical power conversion
5 Reciprocating engines

ASSESSMENT

CC(EE, 1h30')

RECOMMENDED READING

G. SEGUIER Electricité industrielle 2ème édition , éditeur DUNOD

PREREQUISITE

Basic electronical concepts

Module: CONTROL S6		EE16CC	ECTS: **6**
Course: AUTOMATION AND INSTRUMENTATION		**EE16CC4**	Coeff.: **0,333**
LECTURERS(S): **DUMAS P.**			
Lec.: **10** h	Prac.: **10** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The objective of this course is to provide analysis and programming methods to drive industrial Control-Command systems (automation) and show the link between sensors and actuators.
Analysis of Automation Systems or Computer Engineering systems is done with step-transition diagram or finite state machine and Petri net.

LEARNING OUTCOMES

Being able to perform the analysis of an industrial system and program control systems.
Being able to choose an automation equipment.
Recognize limits of control systems and Supervisory Control

DESCRIPTION

INDUSTRIAL INSTRUMENTATION:
Chains measuring and control(sensor, conditioning, actuators)
Reminders on industrial sensors
Automation:
Command Systems(PLC, PC, PAC)
Monitoring, limitations
OPC Standard , client-server concept
SFC Analysis and standardized languages STANDARD 1131-3
Finite State Machine analysis
Petri net

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

PREREQUISITE

MODULE :

Materials and transfers S6

ECTS : 4		MODULE CODE : EE16MT

MODULE LEARNING OUTCOMES:

- Demonstrate skills in steady-state and non steady-state heat transfer by conduction
- Know the key concepts of mechanics of vibration and acoustic transmission
- Demonstrate the ability to understand, to analyse and to produce a technical drafting

MODULE COURSES

COURSE CODES	COURSES
EE16MT1	Heat Conduction II
EE16MT2	Acoustics
EE16MT3	Computer Aided Design

Module: MATERIALS AND TRANSFERS S6		EE16MT	ECTS: 4
Course: HEAT CONDUCTION II		**EE16MT1**	Coeff.: **0,250**
LECTURERS(S): **BEDECARRATS J-P.**			
Lec.: **6** h	Prac.: **10** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

Conduction is one of the three modes of heat transfer. It is met in the large majority of the thermal systems. This part is the continuation of the course "Heat Conduction 1" where more complex problems closer to the industrial problems will be dealt with.

LEARNING OUTCOMES

After this course, the students must:
Be able to judge importance of this mode of thermal transfer
Be able to calculate exchanged heat
Be able to deal with the principal problems of conduction in steady state and non stationary state.

DESCRIPTION

Analytical study of the thermocinetic problems
1. Steady state
- Location and temperature dependent thermal conductivity.
- Effect of internal energy generation
- Fins
- Multidirectional problems
2. Non steady state
- Lumped Thermal Capacity Model (thin body)
- Studies of the thick bodies (various methods of resolution)

ASSESSMENT

CC(EE, 2h, sd, ca)

RECOMMENDED READING

Boundary Value Problems of Heat Conduction. M.N. OZISIK (Dover Publications)
Heat Transfer Handbook. A Bejan, A.D. Kraus (John Wiley & Sons)

PREREQUISITE

Heat conduction I (EC15TM2)

Module: MATERIALS AND TRANSFERS S6		EE16MT	ECTS: 4
Course: ACOUSTICS		**EE16MT2**	Coeff.: **0,500**
LECTURERS(S): **HAILLOT D.**			
Lec.: **10** h	Prac.: **10** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The Engineer in Energetics often has to install very different equipment – heater, ACV or air conditioning- that may have strong acoustic effects on the surrounding environment. Even if the engineer is not an acoustician, he/she has to know the fundamentals of acoustics to consider it in his studies.

LEARNING OUTCOMES

After this course, students should be able to describe mathematically and physically a sound. They may analyze its spectrum, estimate the noise rating associated and propose, if necessary, some improvements.

DESCRIPTION

Introduction
I.Acoustic wave physical characteristics
Definition – Sound wave characteristics –
II.Measure and perception of sounds
Basic indicators (sound levels and filters) – Loudness curves
III. Applied acoustics to the building sector
Insulation and correction
IV.European regulations
Conclusion

ASSESSMENT

CC(EE, 1h30, ca)

RECOMMENDED READING

Acoustique Générale, Potel C. & Bruneau M., 2006, Ellipses.
Acoustique Appliquée, Val M., 2002, Dunod.
Impacts sanitaires du bruit, état des lieux et indicateurs bruit-santé. Agence Française de Sécurité Sanitaire Environnementale (2004)
Normes Française : NF EN 12354-1, NF EN 12354-2, NF EN 12354-3

PREREQUISITE

Module: MATERIALS AND TRANSFERS S6		EE16MT	ECTS: 4
Course: COMPUTER AIDED DESIGN		**EE16MT3**	Coeff.: **0,250**
LECTURERS(S): **GIBOUT S.**			
Lec.: **10** h	Prac.: **10** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

This module provides students with the basic techniques of graphic representation through the use of AutoCAD.
Materials Resistance concepts are also introduced.

LEARNING OUTCOMES

At the end of this course, students should be able to:
• Read, analyze and understand technical drawings
• Produce an unambiguous technical drawing
• Use the key functions of AutoCAD
• Analyze and predict the deformation and stress limits of mechanical parts subject to constraints

DESCRIPTION

Technical Drawing
- Presentation Standards
- Different types of views, sections and cuts
- Quotation
- Representation of common elements (threads, ...)
- Presentation of AutoCAD
Resistance of Materials
- Assumptions and fundamental laws
- Tension / Compression
- Shear
- Twist

ASSESSMENT

CC(EM,da)x1/3 + CC(EE,sd,st,sc,2h)x2/3

RECOMMENDED READING

Guide du dessinateur industriel : pour maîtriser la communication technique, Chevalier Andre (Hachette Supérieur)

PREREQUISITE

MODULE : Chemistry S6		
ECTS : 6		MODULE CODE : EP16CH

MODULE LEARNING OUTCOMES:

- Understand the physicochemical reactions in solution (acid/base, redox potential, etc.)
- Understand the main reaction mechanisms in organic chemistry and polymer chemistry

MODULE COURSES

COURSE CODES	COURSES
EP16CH1	Sensors in Solution
EP16CH2	Macromolecular Organic Chemistry
EP16CH3	Organic Chemistry

Module: CHEMISTRY S6		EP16CH	ECTS: **6**
Course: SENSORS IN SOLUTION		**EP16CH1**	Coeff.: **0,333**
LECTURERS(S): **AUTHIER L.**			
Lec.: **12** h	Prac.: **12** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

The aim of this course is to give to the students the tools allowing the assessment of the chemical reactions and species occurring in solutions

LEARNING OUTCOMES

-know the chemical processes occurring in solutions,
-measure and monitor the chemical composition in solutions by using electrochemical sensors,
-identify the convenient sensor according to the measurement required.

DESCRIPTION

1-Chemistry in solution: acido-basic, redox, complexation and precipitation reactions
2-non-specific sensor with current : measurement of the resistance in solution
3-specific sensor with no current : electrodes of 1st , 2nd and 3rd species ; electrode with monocristal, solid or liquid membrane, soluble gas; crown ether- based PVC electrode ; biosensor.

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

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PREREQUISITE

Basic level of chemistry of solutions

Module: CHEMISTRY S6		EP16CH	ECTS: **6**
Course: MACROMOLECULAR ORGANIC CHEMISTRY		**EP16CH2**	Coeff.: **0,333**
LECTURERS(S): **BOUSQUET A.**			
Lec.: **10** h	Prac.: **6** h	Lab.: **12** h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

This course offers overview of polymer science, from the basic definitions, macromolecular properties, thermomechanical properties to the design techniques for synthetic polymers.

LEARNING OUTCOMES

To get a fundamental knowledge of what a polymer is
To know the molecular characteristics of polymeric chains
To develop a general idea of the use and production of usual polymers
To understand synthesis mechanisms of common polymer

DESCRIPTION

This course offers and overview of polymer science, from the basic definitions, macromolecular properties, thermomechanical properties to the design techniques for synthetic polymers. Microarchitecture knowledge includes tacticity, molecular-weight distribution, sequence distributions in copolymers, errors in chains such as branches, head-to-head addition ect... Studies synthesis of polymeric materials, emphasizing interrelationships of chemical pathways, process conditions, and microarchitecture of molecules produced. Chemical pathways include traditional approaches such as radical polymerization, and step-growth polycondensation. Process conditions include bulk, solution, emulsion, suspension, gas phase, and batch vs. continuous fluidized bed.
Experiments in this class are broadly aimed at acquainting students with the range of properties of polymers, methods of synthesis, and physical chemistry. Some examples of laboratory work include solution polymerization of acrylamide, physical and chemical gels, viscosimetry analysis.

ASSESSMENT

CC(EE, 2h)x8/10 + TP(Tr, Rap)x2/10

RECOMMENDED READING

Chimie et physico-chimie des polymères – Michel Fontanille (Dunod)

PREREQUISITE

Basic Organic Chemistry

Module: CHEMISTRY S6		EP16CH	ECTS: **6**
Course: ORGANIC CHEMISTRY		**EP16CH3**	Coeff.: **0,333**
LECTURERS(S): **TEYSSIER S.**			
Lec.: **12** h	Prac.: **12** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

Basic knowledge and concept in organic and macromolecular chemistry regarding its applications in the following domains: industrial organic chemistry (plastic matters, elastomer, resins, …).

LEARNING OUTCOMES

After this course, students should understand and be able to explain the mechanism of few chemical reactions for each main family of organic and macromolecular compounds.

DESCRIPTION

- the reaction in organic chemistry
- aliphatics hydrocarbons
- aromatics hydrocarbons
- alkyl halides and Grignard compounds
- alcohols and phenols (C-O-H group)
- carbonyl compounds (carbon-oxygen double bond C=O)
- carboxylic acids and derivated (for example : few polymer synthesis)

ASSESSMENT

CC(EE, 2h)

RECOMMENDED READING

Chimie organique, cours - Paul Arnaud (Dunod)
Chimie Organique, Les grands principes - John McMurry (Dunod)

PREREQUISITE

General chemistry (basic organic chemistry)

MODULE : Reactor S6		
ECTS : 4		MODULE CODE : EP16RE

MODULE LEARNING OUTCOMES:

• Identify the simple reaction kinetics
• Demonstrate the ability to perform mass and energy balances on ideal reactors and whole processes (systems)

MODULE COURSES

COURSE CODES	COURSES
EP16RE1	Chemical Kinetics
EP16RE2	Chemical Reaction Engineering

Module: REACTOR S6			EP16RE	ECTS: 4
Course: CHEMICAL KINETICS			EP16RE1	Coeff.: **0,500**
LECTURERS(S): **MARIAS F.**				
Lec.: **12** h	Prac.: **18** h	Lab.: h	Proj.: h	
Mandatory Course		Language : French		

OVERVIEW

The goal of chemical kinetics is to study the rate at which a chemical reaction advances with respect to time. Indeed, a chemical reaction needs time to proceed. This aspect is of particular importance for the design of chemical reactor. The quicker the rate of reaction is the smaller is the size of the reactor where it has to be carried out. Hence this lecture develops this particular field and gives insights into the formalism on which rate of reaction should be taken into account.

LEARNING OUTCOMES

After this course, students should:
-be able to write a mass balance on every ideal reactor
-be able to compute the order of a reaction and its activation energy for simple and complex reaction
-be able to apply their knowledge to design ideal reactors

DESCRIPTION

Part I: Rate of chemical reaction
The definition of the rate of chemical reaction is given in this part. Mass balances are then derived on the Completely Stirred Tank Reactor and on the Plug Flow Reactor
Part II: Homogeneous kinetics. Closed systems at constant volume
This is the main part of the lecture. The mass balance is derived on a batch and completely stirred tank reactor. This law is integrated for reaction rate at order 0, 1 and 2. Concepts such as half time reaction, Arrhenius law, simple reactions, equilibrium, competitive reactions and chain reactions are developed inside this part.

ASSESSMENT

CC(EE, 2H)

RECOMMENDED READING

J. Villermaux, Génie de la reaction chimique.
B. Frémaux, Eléments de cinétique et de catalyse, Tec & Doc, 1989

PREREQUISITE

Introduction to transport phenomena

Module: REACTOR S6		EP16RE	ECTS: 4
Course: CHEMICAL REACTION ENGINEERING		EP16RE2	Coeff.: **0,500**
LECTURERS(S): **MERCADIER J.**			
Lec.: **12** h	Prac.: **12** h	Lab.: h	Proj.: h
Mandatory Course		Language : French	

OVERVIEW

As each chemical plant contains one (or more) reactor, chemical reaction engineering tries to determine the influence of the reactor design and operating conditions on the products of the reaction. This course concerns simple reactor design calculations for ideal reactors.

LEARNING OUTCOMES

At the end of the courses of chemical reaction engineering students will be able to build mass and thermal balance in idealistic reactors (plug flow and completely stirred tank reactor). These balances must be written easily in ordinary conditions but also could be written when the volumetric flow rate changes into the reactor or in case of equilibrate reactions and for several reactions occurring at the same time.

DESCRIPTION

Part I: Material balance in ideal reactors for a single reaction
Ideal batch reactor
Steady state mixed flow reactor
Steady state plug flow reactor
Part II: Multiple reactions
Irreversible series/parallel reactions
Conversion, selectivity, yields
Part III: Thermal behaviour of ideal reactors
Reversible reactions
Optimal temperature progression
Energy balance in a continuous stirred tank reactor, in a plug flow reactor, in a batch reactor
Adiabatic reactor
Reactor's runaway
Data for thermal exchange in industrial reactors

ASSESSMENT

CC(EE, 45 min)x0,35 + CC(EE, da, 1h15)x0,65

RECOMMENDED READING

Levenspiel O., Chemical Reaction Engineering, John Wiley & Sons, 1999 (third edition)
Schweich D., Génie de la réaction chimique, Lavoisier, technique et documentation, 2001
Villermaux J., Génie de la réaction chimique - Conception et fonctionnement des réacteurs, Tech et Doc, 1993 (2ème édition)

Euzen J.P., P. Trambouze , J.P. Wauquier, Méthodologie pour l'extrapolation des procédés chimiques, éditions Technip, 1993
Trambouze P., H. Van Landeghem, J.P. Wauquier, Les réacteurs chimiques (conception, calcul, mise en œuvre), Technip, 1984

PREREQUISITE

Kinetics