الجمهورية الجزائرية الديمقراطية الشعبية People's Democratic Republic of Algeria
وزارة التعليم العالي والبحث العلمي
Ministry of Higher Education and Scientific Research
اللجنة البيداغوجية الوطنية لميدان العلوم و التكنولوجيا
National Pedagogical Committee for the Science and Technology Domain

ACADEMIC MASTER'S HARMONIZED

National Programm

2025 Update

Field	Branch	Major
Sciences and Technologies	***Process Engineering***	***Chemical Engineering***

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Harmonization
Academic Master's

2025 Update

التخصص	الفرع	الميدان
هندسة كيميائية	هندسة الطرائق	علوم و تكنولوجيا

I –Master's Identity Sheet

Access conditions

(Indicate the bachelor's degree specializations that provide access to the Master's program.)

Branch	Harmonized Master	Bachelor's degrees eligible for Master	Ranking according to licence comptability	Coefficient assigned to the licence
Process Engineering	Chemical Engineering	Process Engineering	**1**	**1.00**
		Refening and Petrochemicals	**2**	**0.80**
		Energetics	**3**	**0.70**
		Mineral resources Valorisation	**3**	**0.70**
		Other undergraduate degrees in the ST field	**5**	**0.60**

II – Semester course organization sheets for the specialities

MASTER'S DEGREE IN CHEMICAL ENGINEERING

Semester 1

Teaching Unit	Courses	Credits	Coefficient	Weekly hourly volume			Hourly Volume Semestriel (15 weeks)	Additional work in Consultation (15 weeks)	Evaluation mode	
	Titled			Lecture	TUT	PW			Continuous Assessment	Exam
Fundamental TU Code : FTU 1.1.1 Credits : 10 Coefficients : 5	Unit Operations I (Distillation, Solid-Liquid Extraction, Mixing)	6	3	3h00	1h30		67h30	82H30	40%	60%
	Dispersion and Porous Media	4	2	1h30	1h30		45h00	55h00	40%	60%
Fundamental TU Code : FTU 1.1.2 Credit : 8 Coefficients : 4	Applied Thermodynamics	4	2	1h30	1h30		45h00	55h00	40%	60%
	Heat Exchanger	4	2	1h30	1h30		45h00	55h00	40%	60%
Methodological TU Code : MTU 1.1 Credits : 9 Coefficients : 5	PW Unit Operations I	2	1			1h30	22h30	27h30	100%	
	PW Dispersion and Porous Media	2	1			1h30	22h30	27h30	100%	
	PW Heat Exchanger	2	1			1h30	22h30	27h30	100%	
	Process engineering simulators	3	2	1h30		1h00	37h30	37h30	40%	60%
	Advanced phthon programming	2	2	1h30		1h30	45h00	55h00	40%	60%
Discovery TU Code : DTU 1.1 Credits : 2 Coefficients : 2	Optional course	1	1	1h30			22h30	02h30		100%
Total semester 1		**30**	**17**	**13h30**	**6h00**	**5h30**	**375h00**	**375h00**		

Semester 2

Teaching Unit	Courses	Credits	Coefficient	Weekly hourly volume			Hourly Volume Semestriel (15 weeks)	Additional work in Consultation (15 weeks)	Evaluation mode	
	Titled			Lecture	TUT	PW			Titled	Examen
Fundamental TU Code : FTU 1.2.1 Credits : 10 Coefficients : 5	Unit Operations 2 (Humidification-Drying Evaporation-Crystallization)	6	3	3h00	1h30		67h30	82h30	40%	60%
	Membrane Adsorption and Separation Process	4	2	1h30	1h30		45h00	55h00	40%	60%
Fundamental TU Code : FTU 1.2.2 Credit : 8 Coefficients : 4	Chemical reaction Engineering 1: non ideal reactors and bioreactors	4	2	1h30	1h30		45h00	55h00	40%	60%
	Boilers and Furnaces	4	2	1h30	1h30		45h00	55h00	40%	60%
Methodological TU Code : MTU 1.2 Credits : 9 Coefficients : 5	Numerical Analysis	4	2	1h30	1h30		45h00	55h00	40%	60%
	PW Unit Operations 2	2	1			1h30	22h30	27h30	100%	
	PW Chemical reaction Engineering	2	1			1h30	22h30	27h30	100%	
	PW Membrane Adsorption and Separation Process	1	1			1h00	15h00	15h00	100%	
Discovery TU Code : DTU 1.2 Credits : 3 Coefficients : 3	Compliance with Standards and Rules of Ethics and integrity	1	1	1h30			22h30	2h30		100%
	Elements of applied AI	2	2	1h30	1h30		45h00	5h00	40%	60%
Total semester 2		**30**	**17**	**13h30**	**7h30**	**4h00**	**375h00**	**375h00**		

Semester 3

Teaching Unit	Courses – Titled	Credits	Coefficient	Weekly hourly volume – Lecture	TUT	PW	Hourly Volume Semestriel (15 weeks)	Additional work in Consultation (15 weeks)	Evaluation mode – Titled	Examen
Fundamental TU Code : FTU 2.1.1 Credits : 10 Coefficients : 5	Foundation of modeling in Process Engineering	4	2	1h30	1h30*		45h00	55h00	40%	60%
	Refining and Petrochemicals Process	4	2	1h30	1h30		45h00	55h00	40%	60%
	Process intensification	2	1	1h30			22h30	27h30		100%
Fundamental TU Code : FTU 2.1.2 Credit : 8 Coefficients : 4	Optimization Methods in Process Engineering	4	2	1h30	1h30		45h00	55h00	40%	60%
	Multiphase Reactors	4	2	1h30	1h30		45h00	55h00	40%	60%
Methodological TU Code : MTU 2.1 Credits : 9 Coefficients : 5	Process regulation and control	4	2	1h30	1h30		45h00	55h00	40%	60%
	Experimental design	3	2	1h30		1h00	37h30	37h30	40%	60%
	PW Refining and Petrochemicals	2	1			1h30	22h30	27h30	100%	
Transversal TU Code : TTU 2.1 Credit : 1 Coefficients : 1	Chemical reserve engineering	2	2	1h30	1h30 workshop		45h00	5h00	40%	60%
	Documentary research and thesis design	1	1	1h30			22h30	2h30		100%
Total semestre 3		**30**	**17**	**15h00**	**7h30**	**2h30**	**375h00**	**375h00**		

Note. For the course Foundation of modeling in Process Engineering, the instructor may include practical applications in the form of lab work.

Elective Courses Pool for UED Modules (S1, S2, S3):

1. **Green Chemistry - Clean Processes**
2. **Physicochemical Analysis Methods**
3. **Corrosion and Protection of Industrial Installations**
4. **Activation Processes**
5. **Energy Storage**
6. **Renewable Energies**
7. **Biomass and Biofuels**
8. **Techno-Economic Evaluation of Processes**
9. **Environmental Management**
10. **Renewable Energies**
11. **Industrial Risks and Natural Disasters**
12. **Chemical and Biochemical Sensors**
13. **Bio-fuel Cells (Biopiles)**
14. **Petroleum Cybernetics**

Semester 4

Internship in a company or a research laboratory, concluded by a thesis and an oral defense.

	VHS	Coeff	Crédits
Personal work	550	09	18
Internship in a company or a research laboratory	100	04	06
Seminars	50	02	03
Others (Supervision)	50	02	03
Total Semester 4	750	17	30

This table is provided for information purposes only.

Final Master's Project Evaluation (PFC)

-Scientific Value (Jury's assessment): /6
-Thesis Writing (Jury's assessment): /4
-Presentation and Q&A Session (Jury's assessment): /4
-Supervisor's Appraisal: /3
- Internship Report Presentation (Jury's assessment): /3

III - Detailed Program by Subject - Semester S1

Semester: 1 Teaching Unit: UEF 1.1.1
Subject 1: Unit Operations 1 (Distillation, Solid-Liquid Extraction, Mixing)
TWH: 67h30 (Lecture: 3h00, Tutorial: 1h30)
Credits: 6
Coefficient: 3

Learning Objectives:
By the end of this course, the student should be able to:

- Master process engineering separation techniques (distillation, extraction) and mixing techniques.
- Approach concepts of equipment design and sizing.
- Identify the main operating problems (priming, flooding, entrainment, etc.).

Recommended Prior Knowledge:
Thermodynamics, Differential Equations, Transport Phenomena (Mass Transfer, Fluid Mechanics, etc.).

Course Content:

Chapter 1: Distillation (7 Weeks)

- **Review of Vapor-Liquid Equilibria (VLE).**
- **Flash Distillation:** Bubble point, Dew point.
- **Distillation of Binary Mixtures:**

-McCabe and Thiele Method: Lewis's hypotheses. Operating lines for the rectifying and stripping sections; thermal feed lines (q-line). Determination of the number of theoretical stages, optimal feed location, partial condenser, and partial reboiler. Limiting cases (total reflux, minimum reflux). Multiple feeds and side streams. Murphree efficiency and overall efficiency.

-Ponchon-Savarit Method: Enthalpy-concentration diagram. Material and enthalpy balances on the enrichment and stripping zones and the entire column. Optimal feed position. Minimum number of theoretical stages. Minimum reflux. Partial condenser. Case of two feeds.

Chapter 2: Solid-Liquid Extraction (Leaching) (5 Weeks)

- Solid-liquid equilibrium.
- **Janecke Diagram:** Determination of the number of theoretical stages for counter-current and cross-current extraction.
- Equipment used in batch and continuous operations.

Chapter 3: Mixing (3 Weeks)

- **Applications:** Mixing and dispersion.
- **Types of Agitators:** Different impeller designs.
- **Dimensionless Numbers:** Calculation of Reynolds number, Power number, and Froude number.
- **Design of Agitation Systems:** Impeller diameter, number of baffles, power requirements, and agitator positioning.

Evaluation Mode:

- **Continuous Assessment:** 40% ; **Final Exam:** 60%

Bibliographic References:

1. *Daniel Defives et Alexandre Rojey, Transfert de matière , Efficacité des opérations de séparation du génie chimique, Edition TECHNIP ,1976.*
2. *Robert E. Treybal,«Mass Transfer Operations»,Third Edition, McGraw –Hill ,1980.*
3. *Warren L. Mc Cabe,Julian C. Smith, Peter Harriott«Unit Operations of Chemical Engineering », Mc Graw- Hill, Inc, Fifth Edition, 1993.*
4. *Jean LEYBROS, Extraction liquide-liquide - Description des appareils, Techniques de l'ingénieur Référence J2764 v1, 2004.*
5. *Unit Operations Handbook, Volume 1, Mass transfer, Edited by John J. Mcketta, 1993.*
6. *Daniel Morvan, Génie Chimique : les opérations Unitaires procédés Industriels Cours et Exercices Corrigés, Editeur : ELLIPSES, Colletion :Technosup, 2009.*
7. *Pierre Wuithier, Le pétrole ,Raffinage et Génie chimique, 2 ème édition, 1972.*

Semester: 1
Teaching Unit: UEF 1.1.1
Subject 2: Porous and Dispersed Media
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Learning Objectives:

The objectives of this course are to provide knowledge on the characteristics of porous and dispersed media, as well as their impact on the parameters optimizing solid-liquid unit operations, such as settling velocity, pressure drops, fluidization velocity, etc.

Recommended Prior Knowledge:

Mathematics (surfaces of geometric shapes), Fluid Mechanics (flow regimes), and fundamental Unit Operations.

Course Content:

Chapter 1: Operations on Solids

Definitions. Grain morphology and packing. Properties of solids. Size reduction (Grinding/Crushing), Screening, and Sieving.

Chapter 2: Particle Motion in a Fluid

Fluid flow around particles. Vertical motion of particles or globules in a gravity field. Equation of motion (Terminal velocity). Hindered settling (collective fall of particles in a fluid).

Chapter 3: Fluid Flow through Porous Media

Flow of a single fluid through a bed. Dispersion phenomena. Heat transfer in a fixed bed. Packed columns. Flow of a suspension.

Chapter 4: Fluidization

Characteristics of fluidized systems. Liquid-solid systems. Gas-solid systems. Fluidized beds (gas-solid). Heat and mass transfer between the fluid and the particles.

Chapter 5: Sedimentation (Settling)

Sedimentation of fine particles. Sedimentation of large particles. Kynch Theory. Design and sizing of a clarifier/settler.

Chapter 6: Filtration

Theory of filtration. Constant flow rate filtration vs. Constant pressure filtration. Ruth’s Law. Case of compressible cakes.

Evaluation Mode :

Continuous Assessment: 40% ; **Final Exam :** 60%

Bibliographic References:

Coulson J.M., J.F Richardson, J.R Backhurst And J.H. Harker, "Chemical Engineering", volume two, Fifth edition, Pergamon Press, 2002.

1. Rhodes, M., Introduction to ParticleTechnology, 2nd Ed., Wiley (2008).
2. Gibilaro, L. G., Fluidization - Dynamics, Butterworth - Heinemann (2001).
3. Perry R. H., D. W. Green And J. O. Maloney, "Perry's Chemical Engineers' Handbook " seventh edition, , McGraw Hill, 1999
4. Kunii D. And O. Levenspiel, "Fluidization Engineering", second ed. Butterworth—Heinemann, 1991.
5. Darton R.C., "Fluidization", ed. by J.F. Davidson, R. Clift and D. Harrison, Academic Press, 1985.
6. McCabe W.L., J.C. Smith and P. Harriott, "Unit Operations of Chemical Engineering", seventh edition, ed. McGraw-Hill, 2004.

Semester: 1
Teaching Unit: UEF 1.1.2
Subject 1: Applied thermodynamics
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Objectives:

Study thermodynamic cycles and master the operating principles of certain energy technologies, namely: thermal machines, compressors, pumps, etc.

Recommended Prerequisite Knowledge:

Chemical thermodynamics, fluid mechanics.

Course Content:

Chapter 1: Turbomachinery (07 weeks)

I.1 Pumps
I.2 Fans
I.3 Compressors
I.4 Gas and steam turbines

Chapter 2: Thermodynamic Cycles (04 weeks)

II.1 Thermodynamic cycles and their representation on diagrams ((T,S), (P,V), etc.)
II.2 Power cycles (Rankine, Hirn, Carnot, etc.) and refrigeration cycles (Reversed Carnot, etc.)
II.3 Introduction to Heating and Air Conditioning Systems
II.4 Heat pumps and energy cogeneration

Chapter 3: Thermodynamics of Irreversible Processes (04 weeks)

III.1 Energy conservation in open systems
III.2 Entropy balance of an open system
III.3 Physical and chemical exergy
III.4 Application of exergetic analysis to thermodynamic cycles

Assessment Method:

Continuous assessment: 40% ; Final exam: 60%

Bibliographic References:

1. *Gordon Van Wylen, Richard Sonntag, Thermodynamique appliquée, Editeur Erpi, Collection : Diffusion Pearson Education, 2002.*
2. https://hal.inria.fr/file/index/docid/556977/filename/CycleThermoMachines_1011.pdf
3. http://www.emse.fr/~bonnefoy/Public/Machines_Thermiques-EMSE.pdf
4. *Olivier Cleynen, Thermodynamique de l'ingénieur, Collection Frama book, 2015.*

5. *Paul Chambadal, la turbine à gaz, Collection de la direction des études et recherches d'électricité de France, EYROLLES, 1976.*
6. *Jean Lemale, Les pompes à chaleur, 2éme Edition DUNOD, Paris, 2012, 2014.*
7. *Smith, E.B, Basic, ChemicalThermodynamics, 2nd ed., ClarendonPress, Oxford, 1977.*
8. *Stanley I.Sandler, Chemical and Engineering Thermodynamics, Wiley, New York, 1977.*
9. *Lewis G.N., Randal M., Thermodynamics, Mac Graw Hill*
10. *Hougen O.A., Watson K.M., Chemicalprocessprinciples, Vol II: Thermodynamics, John Wiley and sons*
11. *Brodyanski V., Sorin M., Le Goff P. The efficiency of industrialprocesses, exergyanalysis and optimization, Amsterdam, Elsevier, (1994).*
12. *Wuithier, P, le pétrole, raffinage et génie chimique, édition technip 1972*
13. *Abbott M; Théorie et applications de la thermodynamique, série schum, Paris 1978*
14. *Kireev, V. Cours de chimie physique, Edition Mir, Moscou 1997*

Semester: 1
Teaching Unit: UEF 1.1.2
Subject 2: Heat Exchanger
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Objectives:

To deepen students' knowledge and introduce new concepts such as transient heat transfer, conduction through fins and in the presence of a heat source, heat exchangers, and design/calculation methods for heat transfer equipment.

Recommended Prerequisite Knowledge:

Heat transfer, fluid mechanics, and mathematical background (first- and second-order differential equations, integral calculus, etc.).

Course Content:

Chapter 1: Review of Heat Transfer Laws **(1 week)**
Chapter 2: Flow Around an Obstacle **(4 weeks)**
Flow over a flat plate; flow around a tube, cylinder, and sphere; correlations and estimation of the heat transfer coefficient; Flow around a tube bundle; correlations
Chapter 3: Flow Inside Tubes **(3 weeks)**
Correlations and estimation of the heat transfer coefficient
Chapter 4: Description of Heat Exchangers Without Phase Change **(1 week)**
Double-pipe heat exchangers; Shell-and-tube heat exchangers (shell, tube bundle, and shell-bundle assembly); Plate heat exchangers
Chapter 5: Heat Exchanger Design and Calculation **(3 weeks)**
Heat transfer analysis (fundamental equations, log mean temperature difference, overall heat transfer coefficient U); Pressure drop analysis (pressure drop inside tubes, pressure drop outside tubes)
Design methods:

- Design of a double-pipe heat exchanger
- Design of a shell-and-tube heat exchanger (Kern method)

General considerations in shell-and-tube exchanger design and calculation programming

Chapter 6: Heat Exchangers with Phase Change **(3 weeks)**
Description of equipment; Condensation of a pure vapor (film condensation coefficients outside tubes, condenser design, condensation preceded by vapor desuperheating and followed by condensate cooling); Condensation of a multicomponent vapor (individual heat transfer coefficient calculation – Ward method and Kern method, shell-side pressure drop, design example); Submerged forced-circulation reboilers (boiling of a pure component in the shell, boiling of a mixture in the shell); Natural circulation reboilers (thermosiphon reboilers); Submerged natural-circulation reboilers; Example of reboiler design calculation

Assessment Method:

Continuous assessment: 40%; Final exam: 60%

Bibliographic References:

1. *J.F. Sacadura, Transferts thermiques – Initiation et approfondissement, Ed. Lavoisier, 2015.*
2. *R.B Bird, W.E. Stewart, E.N. Lightfoot, Transport phenomena, 2ème Ed., Wiley & Sons, 2007.*
   A. Giovannini et B. Bédat, Transfert de chaleur, Ed. Cépaduès, 2012.
3. *James R. Welty, Charkes E. Qicks, Robert E. Wilson; Gregory Rorrer, Fundamentals of Momentum, Heat, and Mass Transfer. 4theditionWiley& Sons, 2001.*
4. *Leontiev, Théorie des échanges de chaleur et de masse – Édition Mir-Moscou*
5. *H.W. Mac Addams La transmission de la chaleur - Dunod - Paris*
6. *F. P. Incropera, D. P. Dewitt - Fundamentals of Heat and Mass Transfer - Wiley, N.Y. - 2002*
7. *Bontemps, A. Garrigue, C. Goubier, J. Huetz, C. Marvillet, P. Mercier Et R. Vidil – Échangeur de chaleur – Technique de l'Ingénieur, Traité Génie Énergétique*
8. *P. Wuithier, Le Pétrole, Raffinage et Génie Chimique tome2, Edition technip Paris*

Semester: 1
Teaching Unit: UEM 1.1
Subject 1: PW Unit Operations I
TWH: 22h30 (PW: 1h30)
Credits: 2
Coefficient: 1

Course Objectives

Enable students to apply theoretical knowledge to practical situations and to visualize specific physical and chemical phenomena.

Professional Skills

Develop teamwork skills, ensure strict adherence to safety protocols, and build awareness of the risks associated with laboratory equipment, industrial installations, and processes.

Recommended Prior Knowledge

To successfully complete this course, students should have a solid background in:

- Thermodynamics
- Transport Phenomena (Mass Transfer, Fluid Mechanics, etc.)

Course Content: Laboratory Work (TP)

PW 1	Determination of the mutual solubility of two partially miscible liquids (Water–Phenol system).
PW 2	Extraction of caffeine from tea.
PW 3	Separation of benzoic acid and 2-naphthol.
PW 4	Study of a batch liquid–liquid extraction process.
PW 5	Study of various phase diagrams.
PW 6	Absorption of CO_2 from an air stream using water (physical absorption).
PW 7	Absorption with chemical reaction and solvent regeneration: CO_2 absorption using amino acid solutions.
PW 8	Gas–liquid absorption and desorption.
PW 9	Construction of a ternary phase diagram (Water/Oil/Surfactant system).

Assessment Method

Continuous Assessment: 100%

Semester :1
Teaching Unit: UEM 1.1
Subject 2: PW Dispersion and Porous Media
TWH: 22h30 (PW: 1h30)
Credits: 2
Coefficient: 1

Course Objectives

- Apply the theoretical concepts acquired in the course.
- Learn how to start up, operate, and shut down an installation in compliance with safety regulations.

Recommended Prior Knowledge

Unit Operations

Course Content: Practical Work (PW)

PW No. 1: Characterization of solid particles: density, bed porosity, and flow angles.

PW No. 2: Determination of average particle diameters by sieving.

PW No. 3: Measurement of pressure drop through a packed bed; fluidization study.

PW No. 4: Gas–solid or liquid–solid fluidization: minimum fluidization velocity, heat transfer, and bed expansion.

PW No. 5: Filtration: filter press operation, cake resistance, and filter medium resistance.

PW No. 6: Grinding.

Assessment Method

Continuous Assessment: 100%

Semester :1
Teaching Unit: UEM 1.1
Subject 3: PW Heat Exchanger
TWH: 22h30 (PW: 1h00)
Credits: 2
Coefficient: 1

Course Objectives

- Experimentally quantify the different modes of heat transfer.
- Measure the thermal performance of various types of heat exchangers.
- Experimentally study equipment used for the production, transport, and utilization of steam.

Recommended Prior Knowledge

- Transport Phenomena
- Fluid Mechanics

Course Content: Practical Work (PW)

PW No. 1: Heat transfer by conduction (basic unit).

PW No. 2: Linear heat conduction.

PW No. 3: Radial heat conduction.

PW No. 4: Convection and radiation.

PW No. 5: Heat transfer by free and forced convection.

PW No. 6: Coaxial (double-pipe) heat exchanger.

PW No. 7: Plate heat exchanger: enthalpy balances, efficiency curves, and evaluation of heat transfer coefficients.

PW No. 8: Shell-and-tube heat exchanger.

Assessment Method

Continuous Assessment: 100%.

Semester :1
Teaching Unit: UEM 1.1
Subject 4: Process engineering simulators
TWH: 37h30 (Lecture: 1h30, PW: 1h00)
Credits: 2
Coefficient: 1

Course Objectives

Through this course, students learn how to design, size, and simulate selected industrial processes related to chemical/process engineering using simulation software (calculation code in the form of a process simulator).

The program content will be adapted according to the simulator used.

Recommended Prior Knowledge

- Thermodynamics
- Transport Phenomena
- Unit Operations

Course Content

Chapter I: Review (2 weeks)

- Process engineering simulators
- Creating a simulation
- Selection of chemical components
- Choice of thermodynamic model
- Installation and specification of material streams
- Simulation of pumps, compressors, and flash separators

Chapter II: Simulation of Reactions and Chemical Reactors/Bioreactors (3 weeks)

- Single conversion reactions
- Multiple conversion reactions
- Equilibrium reactions
- Continuous Stirred Tank Reactors (CSTR)
- Plug Flow Reactors (PFR)
- Bioreactors
- Catalytic reactors
- Reactor networks (reactor combinations)

Chapter III: Simulation of Gas–Liquid, Liquid–Liquid, and Liquid–Solid Contactors (3 weeks)

- Simulation of absorption and stripping processes with and without chemical reactions in different column configurations (tray columns and packed columns)
- Liquid–liquid extraction ; Liquid–solid extraction

Chapter IV: Simulation of Distillation Columns (3 weeks)

- Distillation of binary and complex mixtures
- Simulation of different column configurations (tray and packed columns)
- Total and partial reflux
- Total and partial condensers

Chapter V: Simulation of Real Industrial Processes (4 weeks)

- Applications to various real chemical processes

Assessment Method

- Continuous Assessment: 40% ; Final Exam: 60%
-

Bibliographic References:

1- Mariano Martín Martín, Introduction to Software for ChemicalEngineers, 2014.
2- Xavier Julia, Simulateurs de procédés, techniques de l'ingénieur, J1022 V2.
3- User guide du simulateur utilisé.

Semester :1
Teaching Unit: UEM 1.1.1
Subject 5: Advanced phthon programming
TWH: 45h00 (Lecture: 1h30, PW: 1h30)
Credits: 2
Coefficient: 2

Course Objectives

Targeted Skills

- Use of digital tools for acquiring, processing, producing, and disseminating information
- Python programming and project management skills
- Automation and data visualization skills

Objectives

- Strengthen proficiency in Python and introduce students to the fundamentals of data analysis and artificial intelligence
- Acquire solid foundations in computer science
- Learn programming using Python and Excel
- Master task automation
- Master the use of project management software

Required Materials

- A computer with Python installed
- Python libraries: NumPy, Pandas, Scikit-learn, Matplotlib, os (os.listdir, os.path.exists, os.mkdir, os.rmdir), Seaborn, Plotly, Requests, Beautiful Soup, Tkinter, PyQt
- TensorFlow, PyTorch

Prerequisites

- Python programming

Course Content

Chapter 1: Python Programming Review (2 weeks)

1. Introduction: Basic computer science concepts and digital tools; Python installation
2. Operating systems: roles and types (Linux, Windows, etc.), task management and priorities
3. Computer networks: principles, IP addresses, DNS, Internet
4. Basic programming: interactive mode vs script mode, variables, data types, operators, conditional structures (if), loops (for, while)
5. Functions and essential elements: built-in functions, user-defined functions, standard modules (math, random), strings, lists, basic data manipulation
6. Files, lists, tuples, dictionaries
7. Exercises:
   - Python practice exercises
   - Exercises using libraries covered in class (math, random, NumPy, Pandas, etc.)

Chapter 2: Programming and Automation (4 weeks)

1. Principles of Task Automation

- Python libraries for automation:
  - Pandas and NumPy
  - os, shutil (file and folder manipulation)
  - openpyxl or pandas (Excel/CSV processing)
- Definitions and examples (e.g., automated email sending)

2. File Handling with Python

- Browsing directories (os.listdir)
- Checking file/folder existence (os.path.exists)
- Creating/removing directories (os.mkdir, os.rmdir)
- Data visualization: Matplotlib, Seaborn, Plotly
- Requests for interacting with APIs
- Beautiful Soup for data scraping
- Tkinter, PyQt for graphical interfaces
- Copying/moving files with shutil
- Searching, sorting, and generating simple reports
- Serialization and deserialization (pickle module)
- Object serialization and large file processing (streaming)

3. Exercises

- Using openpyxl and pandas to:
  - Create automated reports
  - Automatically extract data
- Writing scripts to:
  - Process text files (searching, sorting)
  - Automate technical calculations
  - Generate simple reports (PDF, Excel)
- Sorting algorithms (including insertion sort)
- Implementing search functions
- File operations
- Basic secure networking (simple configurations, password management)

Chapter 3: Advanced Excel Training (2 weeks)

1. Macros and creation of simple macros
2. Pivot tables
3. Histograms
4. Bar charts
5. Radar charts
6. Practical exercises

Chapter 4: GanttProject Training (2 weeks)

1. Introduction to project management:
   - Definition of a project

   - Project management challenges
   - GanttProject interface
2. Task creation, modification, and organization
3. Time management (start/end dates)
4. Resource management
5. Practical exercises

Chapter 5: Advanced Object-Oriented Programming (3 weeks)

1. Code organization:
   - Custom functions, parameters, return values
   - Modules, imports, packages
2. Complex data structures:
   - Lists, tuples, dictionaries (creation, modification, iteration)
3. OOP fundamentals:
   - Classes, objects, attributes, methods
   - Public, private, protected attributes
4. Special methods:
   - `__init__`, `__str__`, `__repr__`, `__len__`
5. Advanced concepts:
   - Encapsulation, abstraction, inheritance, polymorphism
   - Advanced inheritance, decorators, design patterns, metaclasses
6. Exercises

Chapter 6: Introduction to Data for Artificial Intelligence (2 weeks)

1. Common AI datasets:
   - Iris, MNIST, CIFAR-10, Boston Housing, ImageNet
2. Data preprocessing:
   - Cleaning, normalization, encoding, train-test splitting
   - Cross-validation
3. Feature engineering:
   - Feature selection
   - Feature creation
   - Dimensionality reduction
4. Key AI libraries:
   - Scikit-learn, TensorFlow, Keras, PyTorch
5. Exercises

Practical Work

PW 01: Python Programming Fundamentals

- Control structures, data types, loops, basic functions
- Reading and processing text files
- Generating simple reports (PDF, Excel)

PW 02: Automation Mini-Project

Develop specifications for a mini automation project in Python:

- Load data (e.g., experimental measurements)
- Compute statistics (mean, standard deviation with interpretation)
- Generate graphs
- Send results via email

PW 03: Excel Programming

- Dashboard development
- Automated Excel sheets
- Simple macros
- Conditional formulas
- VLOOKUP

PW 04: Organizing a Meeting Using GanttProject

- Create a new project
- Define tasks and subtasks
- Assign resources
- Estimate durations
- Create and analyze Gantt chart
- Monitor progress

PW 05: Advanced code organization
PW 06: Advanced OOP in Python
PW 07: File handling and data analysis
PW 08: AI dataset preparation and processing
Final Project

Title: Data Analysis and Visualization + Simple Predictive Model

Skills Applied:
Data loading, object-oriented programming, advanced structures, Pandas, Scikit-learn

Deliverables:

- Oral presentation
- Written report

Assessment Method

- Final Exam: 60% ;Continuous Assessment: 40%

Bibliographic References:

[1] . E.Schultz et M.Bussonnier (2020) : Python pour les SHS. Introduction à la programmation de données. Presses Universitaires de Rennes.

[2] . C.Paroissin, (2021) : Pratique de la data science avec R : arranger, visualiser, analyser et présenter des données. Paris : Ellipses, DL 2021.

[3] . S.Balech et C.Benavent : NLP texte minig V4.0, (Paris Dauphine – 12/2019) : lien : htPWs://www.researchgate.net/publication/337744581_NLP_text_mining_V40_-_une_introduction_-_cours_programme_doctoral

[4] . Allen B. Downey Think Python: How to Think Like a Computer Scientist, O'Reilly Media, 2015;
[5] . Ramalho, L.. Fluent Python. " O'Reilly Media, Inc.", 2022;
[6] . Swinnen, G.. Apprendre à programmer avec Python 3. Editions Eyrolles, 2012;
[7] . Matthes, E. Python crash course: A hands-on, project-based introduction to programming. no starch press, 2019
[8] . Cyrille, H. (2018). Apprendre à programmer avec Python 3. Eyrolles, 6ème édition. ISBN: 978-2212675214
[9] . Daniel, I. (2024). Apprendre à coder en Python, J'ai lu
[10] . Nicolas, B. (2024). Python, du grand débutant à la programmation objet Cours et exercices corrigés, 3eme édition, Ellipses
[11] . Ludivine, C. (2024). Selenium Maîtrisez vos tests fonctionnels avec Python, Eni

Ressources en ligne :

- Documentation officielle Python : docs.python.org
- Exercices Python sur Codecademy : codecademy.com/learn/learn-python-3
- W3Schools Python Tutorial : w3schools.com/python/

Semester :1
Teaching Unit: UED 1.1
Subject 1: Green Chemistry - Clean Processes
TWH: 22h30 (Lecture: 1h30)
Credits: 1
Coefficient: 1

Course Objectives

Develop information management methods aimed at structuring and capitalizing data in order to ensure rapid and reliable access to solutions that enable the evolution of production processes toward cleaner processes using minimal materials and energy, while taking environmental protection into account.

Recommended Prior Knowledge

- Basic knowledge of Process Engineering

Course Content
Chapter 1: Green Chemistry (2 weeks)

- The 12 Principles of Green Chemistry

Chapter 2: Tools for Clean Process Engineering (5 weeks)

- **Sustainable process design methodology:**
  - Multicriteria approach
  - Concept of sustainable development in Process Engineering
  - System boundaries
  - Design of sustainable processes
- **Process optimization strategies:**
  - Case studies and types of resulting optimizations
  - Optimization methods
- **Process representation and modeling:**
  - Computational aspects
  - Representation of phenomena using bond graphs
  - Application of bond graphs to process engineering:
    - Finite-dimensional systems
    - Infinite-dimensional systems

Chapter 3: Innovative Technologies and Methods for Process Intensification (4 weeks)

- **Process miniaturization:**
  - Principles of intensification through miniaturization
  - Miniaturized mixers, contactors, and heat exchangers
  - Selected industrial applications
- Multifunctional reactors
- Ultrasound in process engineering (sonochemical engineering)
- Microwave technology in process engineering
- Intensification through formulation

Chapter 4: New Generation of Processes (4 weeks)

- Supercritical fluids
- Ionic liquids
- Water as a solvent and solvent-free reactions
- Electrochemical processes for sustainable development
- Photocatalytic engineering
- Biocatalysis and bioprocesses
- Contribution of catalysis to sustainable chemistry

Assessment Method

Final Exam: 100%

Bibliographic References:

1. *S. Suresh, S. Sundaramoorthy, Green Chemical Engineering. An Introduction to Catalysis, Kinetics, and Chemical Processes, CRC Press, 2015.*
2. *Paul T. Anastas, Handbook of Green Chemistry. Green Processes, Volume Editors: Robert Boethling, AdelinaVoutchkova, Volume 9: Designing Safer Chemicals, Wiley-VCH, 2012.*
3. *Martine Poux, Patrick Cognet, Christophe Gourdon, Green Process Engineering from Concepts to Industrial Applications, CRC Press, 2010.*

Semester :1
Teaching Unit: UED 1.1
Subject 2: Physicochemical Methods of Analysis
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 2
Coefficient: 2

Course Objectives

Provide fundamental knowledge of experimental methods and techniques used to characterize matter and study its structure, with particular emphasis on techniques and tools that have recently benefited from technological advances.

Recommended Prior Knowledge

- States of matter
- Chemical thermodynamics
- Structural and physicochemical properties of matter
- Basic concepts in physics and general chemistry

Course Content

Chapter 1: Separation Techniques – Chromatography (2 weeks)

- General principles
- Classification of chromatographic techniques:
  - Column chromatography
  - Thin-layer chromatography (TLC)

Chapter 2: Types of Chromatography (3 weeks)

- Gas chromatography (GC)
- High-performance liquid chromatography (HPLC)
- Thin-layer chromatography (TLC)

Chapter 3: Hyphenated Techniques (2 weeks)

- Gas chromatography–mass spectrometry (GC/MS)
- Liquid chromatography–mass spectrometry (LC/MS)

Chapter 4: Atomic Absorption Spectrometry (2 weeks)

- General principles
- Instrumentation and applications
- Standard addition method

Chapter 5: Atomic Emission Spectrophotometry (2 weeks)

- General principles
- Instrumentation and applications
- Internal standard method

Chapter 6: X-ray Fluorescence Spectrometry (2 weeks)

- General principles
- Applications and advantages

Chapter 7: Thermal Analysis (2 weeks)

- Instrumentation
- Techniques

Assessment Method

- Continuous Assessment: 40%. Final Exam: 60%

Bibliographic References:

1- *J. Tranchant, Manuel pratique de chromatographie en phase gazeuse, Masson, Paris 1995.*
2- *F. Rouessac et A. Rouessac, Méthodes et techniques instrumentales modernes, Dunod, Paris 2004.*
3- *P. Arnaud, Chimie organique, Dunod, 2009.*
4- *A.Skoog, F.Holler et A. Niemaw, Principes d'analyse instrumentale, Edition de Boeck, Paris 20*

III - Detailed Program by Subject - Semester S2

Semester: 2
Teaching Unit: UEF 1.2.1
Subject 1: Unit Operations 1 (*Humidification-Drying Evaporation-Crystallization)*
TWH: 67h30 (Lecture: 3h00, Tutorial: 1h30)
Credits: 6
Coefficient: 3

Course Objectives

By the end of this module, students will have acquired the knowledge necessary to understand simultaneous heat and mass transfer phenomena and to size selected industrial equipment.

Recommended Prior Knowledge

Transport phenomena (mass, momentum, and heat transfer), thermodynamics, mathematics, and unit operations studied at the undergraduate level.

Course Content

Chapter 1: Humidification (6 weeks)

Principles and applications. Humidity-related properties. Equipment used such as cooling towers and air coolers. Psychrometric diagrams. Wet-bulb thermometer. Mixing of humid air including calculation of humid properties of mixtures and use of the Mollier diagram (enthalpy and absolute humidity). Cooling tower design.

Chapter 2: Drying (3 weeks)

General principles. Different types of dryers and selection criteria. Drying modes including continuous, batch, counter-current, co-current, convection, and conduction. Drying mechanisms. Material and enthalpy balances in a dryer. Calculation of drying rate and drying time.

Chapter 3: Evaporation (3 weeks)

Introduction. Main factors influencing evaporation. Simplified heat and mass balances in evaporators. Types of evaporators and circulation modes. Heat transfer area calculation for single-effect and multiple-effect evaporators. Comparison between counter-current and co-current multiple-effect evaporation. Evaporation processes including vapor compression, ejector-compression, heat pump, and absorption systems. Auxiliary equipment such as condensers and gas–liquid separators.

Chapter 4: Crystallization (3 weeks)

Fundamental aspects. Stages of crystallization. Effect of impurities on crystal formation. Batch and continuous crystallization reactors. Adsorption of a solute in liquid phase in a fixed-bed column (percolation).

Assessment Method

Continuous Assessment: 40% ; Final Exam: 60%.

Bibliographic References

1. *Daniel Morvan, Génie Chimique : les opérations Unitaires procédés Industriels Cours et Exercices Corrigés, Editeur : ELLIPSES, Colletion :Technosup, 2009.*
2. *Warren L. MCCabe,Julian C. Smith,, Peter Harriott « Unit Operations of Chemical engineering », Seventh Edition MC Graw Hill,2005.*
3. *Unit Operations Handbook, Volume 1, Mass transfer, Edited by John J. Mcketta, 1993.*
4. *Robert E. Treybal,«Mass Transfer Operations»,Third Edition, McGraw –Hill ,1980.*
5. *Georges Arditti, Technologie chimique industrielle, Tome 3, Production de la chaleur Transfert de matière utilisant l'énergie, Editions EYROLLES, 1972.*

Semester: 2
Teaching Unit: UEF 1.2.1
Subject 2: Membrane Adsorption and Separation Process
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Objectives

The objective of this course is to provide the theoretical foundations necessary for the implementation of adsorbents and for the design of various types of adsorbers, including batch, semi-continuous, and continuous systems. It also aims to provide in-depth theoretical and practical knowledge in membrane technologies and to familiarize students with the latest technological advances in membrane processes.

Recommended Prior Knowledge

Transport phenomena (mass transfer, fluid mechanics, etc.), surface chemistry, and heterogeneous catalysis.

Course Content

Part I: Adsorption Processes (6 weeks)

Chapter 1: Main industrial adsorbents, selection criteria, regeneration methods, and principal industrial applications.
Chapter 2: Adsorption dynamics, preceded by a review of the general laws of physical adsorption.
Chapter 3: Batch adsorption processes.
Chapter 4: Adsorptive separation processes including pressure swing adsorption and temperature swing adsorption.

Part II: Membrane Separation Processes

Chapter 1 (1 week): General concepts and definitions related to membrane processes.
Chapter 2 (3 weeks): Membrane structure, characterization, and industrial membrane modules.
Chapter 3 (5 weeks): Microfiltration, ultrafiltration, nanofiltration, reverse osmosis, and electrodialysis.

Assessment Method

Continuous Assessment: 40% ; Final Exam: 60%.

Bibliographic References

1. *Unit Operations Handbook, Volume 1, Mass transfer, Edited by John J. Mcketta, 1993.*
2. *Warren L. Mc Cabe,Julian C. Smith, Peter Harriott«Unit Operations of Chemical Engineering », Mc Graw- Hill, Inc, Fifth Edition, 1993.*
3. *J. P. Brun, Procédés deséparation par membranes, Transport Techniques membranaires Applications, Masson, Paris, 1988.*
4. *Robert E. Treybal,«Mass Transfer Operations»,Third Edition, McGraw –Hill ,1980.*

Semester: 2
Teaching Unit: UEF 1.2.2
Subject 1: Chemical reaction Engineering 1: non ideal reactors and bioreactors
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Objectives

By the end of this course, students will have acquired knowledge related to hydrodynamics in real (non-ideal) reactors, the main models of homogeneous reactors, and fundamental concepts concerning the operation of bioreactors.

Recommended Prior Knowledge

Basic knowledge of chemical kinetics, thermodynamics, transport phenomena, and ideal homogeneous reactors.

Course Content

Chapter 1: Non-Ideal Reactors (7 weeks)

Fundamental concepts (introduction and definitions). Reactor modeling and the concept of residence time distribution (RTD). Reactor identification. Non-isothermal and adiabatic reactors. Simple models including plug flow reactor with axial dispersion. Multi-parameter models. Mixing states (micromixing and macromixing).

Chapter 2: Bioreactors (8 weeks)

Classification and characteristics of bioreactors. Mass transfer in bioreactors and transfer–reaction coupling. Mechanisms and kinetics of homogeneous and heterogeneous enzymatic reactions. Operating modes including continuous stirred tank reactors, fixed-bed reactors, fluidized-bed reactors, and membrane reactors.

Assessment Method

Continuous Assessment: 40% ; Final Exam: 60%.

Bibliographic References

1. *Levinspiel O : chemicalreaction engineering, 3ème édition, John Wiley and Sons, New York (1998) ISBN : 0471225424X*
2. *Villermaux J : Génie de la réaction chimique, conception et fonctionnement des réacteurs, 2ème édition, Tec § Doc Lavoisier , Paris (1993) ISBN : 2-85206-132-5*
3. *Schweich D : génie de la réaction chimique, Tec ! Doc lavoisier (2001) ISBN : 2-7430-0459-2*
4. *Froment G and BischoffKB : Chemical reactor, analysis and design : John Wiley and Sons, New York (1979) ISBN : 978-0471510-444*
5. *P.trambouze : les réacteurs chimiques : conception / calcul/mise en œuvre, Editions Technip(Paris) 1984*
6. *R.W.Missen : chemicalreaction engineering and kinetics, Edition John Wiley and Sons, Inc, New York, 1999*

Semester: 2
Teaching Unit: UEF 1.2.2
Subject 2: Boilers and Furnaces
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Objectives:

- ✓ Explain the operation of industrial furnaces and boilers.
- ✓ Establish the energy balance of a furnace or a boiler and determine the thermal efficiency of the equipment.
- ✓ Identify the sources of energy losses in these units and methods to optimize the thermal balance.
- ✓ Describe the main operating procedures of heating equipment.

Recommended Prior Knowledge:
Mass, heat and momentum transfer phenomena, and thermodynamics.
Course Content:
Chapter 1. INTRODUCTION (1 week)

Chapter 2. FUELS AND COMBUSTION ENERGY (4 weeks)
Fuels; Combustion; Combustion reactions; Combustion quality; Combustion equipment; Environmental aspects related to combustion.

Chapter 3. INDUSTRIAL FURNACES (6 weeks)

- Classification and description of industrial furnaces. Continuous furnaces, batch furnaces, direct heating and indirect heating, high- and low-temperature furnaces, furnace sizing.
- Energy balance of a furnace.
- Furnace efficiency.
- Operation of industrial furnaces (main operations): Drying, start-up and operational control, furnace shutdown, decoking of furnace tubes.

Chapter 4. INDUSTRIAL BOILERS (4 weeks)
4.1 Role of industrial boilers.
4.2 Thermodynamic aspects of boilers.
4.3 Different types of boilers: Water-tube boilers, fire-tube boilers, heat recovery boilers.
4.4 Water circulation in boilers.
4.5 Thermal calculation of a boiler.
4.6 Main parameters to monitor during boiler operation.

Assessment Method: Continuous Assessment: 40% ; Final Exam: 60%.

Bibliographic References:

1. *R.Borghi, M.Destriau, , Gérard de Soete, Combustion and Flames, Chemical and physicalprinciples, Edition TECHNIP, 1998.*
2. *R.Borghi, M.Destriau, Gérard de Soete, La combustion et les flammes, Edition TECHNIP, 1995.*
3. *htPW://www.ultimheat.com/Museum/section3/1932%20ca%20Galopin%20chaudi%C3%A8res %2020111015.pdf*
4. *Irvin Glassman, Combustion, Second edition , ACADEMIC PRESS, INC, 1987.*
5. *Georges Monnot, La Combustion dans les fours et les chaudières, Technip, Publications de l'Institut français du pétrole, 1978.*

Semester: 2
Teaching Unit: UEM 1.2
Subject 1: Numerical Analysis
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Objectives:
Study the basic methods of numerical analysis.

Recommended Prior Knowledge:
Courses in Calculus, Differential Equations, etc.

Course Content:
Chapter 1: Introduction
Mathematical modeling of transport phenomena. Conservation principles, continuity equation, energy equation, and species conservation equation.
Chapter 2: Classification of Partial Differential Equations
Classification from a mathematical point of view. Classification from a physical point of view.
Chapter 3: Discretization Methods
Finite difference method (detailed). Finite volume method (detailed). Finite element method.
Chapter 4: Elliptic Equations
1D steady-state conduction: Mesh generation, interface conductivity, linearization of source term, boundary conditions, and solution of linear algebraic equations (TDMA method). 2D and 3D conduction: Solution of algebraic equations (Gauss-Seidel method, Relaxation method).

Assessment Method:
Continuous Assessment: 100%.

References:

Semester: 2
Teaching Unit: UEM 1.2
Subject 2: PW Unit Operations 2
TWH: 22h30 (PW: 1h30)
Credits: 2
Coefficient: 1

Course Objectives:
Apply concepts related to unit operations in Process Engineering, including phase equilibria, material balances, and mass transfer.

Recommended Prior Knowledge:
Thermodynamics, Transport Phenomena, Surface Chemistry and Heterogeneous Catalysis, and Liquid–Liquid Extraction.

Course Content:
PW No. 1: Evaluation of the cooling tower efficiency.
PW No. 2: Procedure for calculating water lost by the solid.
PW No. 3: Drying of an organic phase.
PW No. 4: Spray drying (sodium sulfate): material and enthalpy balances, wet-bulb temperature.
PW No. 5: Evaporation of an organic solvent.
PW No. 6: Purification by recrystallization.
PW No. 7: Drying of solids.

Assessment Method:
Continuous Assessment: 100%.

Note: At least four unit operation practical works (PW) are conducted according to available resources; other PWs may be adopted with the approval of the scientific and educational authorities.

Semester: 2
Teaching Unit: UEM 1.2
Subject 3: PW Chemical reaction Engineering
TWH: 22h30 (PW: 1h30)
Credits: 2
Coefficient: 1

Course Objectives:
Assess the student's ability to carry out a practical work aimed at studying the operation of a reactor using the knowledge acquired during the course or at the beginning of the practical work, and evaluate their ability to produce a scientific report highlighting the main results obtained.

Recommended Prior Knowledge:
Homogeneous reactor, transport phenomena.

Course Content:
PW No. 1: Continuous stirred tank reactor (CSTR) practical.
PW No. 2: Plug flow reactor (PFR) practical.
PW No. 3: Series reactors practical.
PW No. 4: Bioproduction: ethanol production by fermentation.
PW No. 5: Photosynthesis: Demonstration of gas exchange with aquatic plants.

Assessment Method:
Continuous Assessment: 100%.

Semester: 2
Teaching Unit: UEM 1.2
Subject 4: PW Membrane Adsorption and Separation Process
TWH: 15h00 (PW: 1h00)
Credits: 1
Coefficient: 1

Course Objectives:
Learn to perform reliable measurements in adsorption and membrane separations, develop critical thinking, and learn to interpret and present results.

Recommended Prior Knowledge:
Thermodynamics, Transport Phenomena, Surface Chemistry.

Course Content:
PW No. 1: Separation of a dye in aqueous phase by adsorption.
PW No. 2: Separation of a pesticide in aqueous phase by adsorption.
PW No. 3: Equilibrium in heterogeneous systems: experimental determination of the adsorption isotherm of CH_3COOH dissolved in water on a solid substance (activated carbon).
PW No. 4: Liquid membrane extraction (emulsion).
PW No. 5: Preparation and stabilization of an emulsion.

Assessment Method:
Continuous Assessment: 100%.

Note: At least four practical works (PW) in adsorption and membrane separation processes are conducted according to available resources; additional PWs may be adopted with the approval of the scientific and educational authorities.

Semester: 2
Teaching Unit: UET 1.2
Subject 1: Elements of applied AI
TWH: 45h00 (Lecture: 1h30, PW l: 1h30)
Credits: 2
Coefficient: 2

Target Skills:

- Identify opportunities for artificial intelligence (AI) in engineering sciences.
- Understand ethical implications of AI and best practices for its use.
- Ability to apply AI techniques to problem solving.

Objectives:

- Master AI algorithms.
- Introduction to fundamental concepts, tools, and applications of modern AI, with emphasis on practical use of Python and its libraries.
- Deepen Python skills.
- Understand AI approaches for problem solving.

Prerequisites:
Advanced Python programming.

Required Materials:

- A computer with Python installed.
- Python libraries: NumPy, Pandas, Scikit-learn, Matplotlib, os.listdir, os.path.exists, os.mkdir, os.rmdir, Seaborn, Plotly, Requests, Beautiful Soup, Tkinter, PyQT, etc.
- TensorFlow, PyTorch, etc.

Course Content:
Chapter 1: Introduction to AI (1 week)

1. Definitions and AI application fields.
2. Historical evolution of AI.
3. Overview of main domains:

- Machine Learning
- Deep Learning

Chapter 2: Basic Mathematics for AI (1 week)

1. Linear algebra: vectors, matrices, products, norms.
2. Probability & statistics: variables, expectation, variance; common distributions: normal, binomial, uniform.
3. Simple linear regression: formulation, cost, optimization; implementation with Scikit-learn.
4. Exercises:

- Matrix manipulation with NumPy.
- Linear regression with Scikit-learn.

- Plotting with Matplotlib.

Chapter 3: Machine Learning (3 weeks)

1. Key concepts: data, models, features, labels, generalization.
2. ML pipeline: training, validation, testing.
3. Learning types: supervised, unsupervised, reinforcement (overview).
4. Exercises: reinforce course concepts.

Chapter 4: Supervised Classification (3 weeks)

1. Training principle for simple classification models.
2. Models and algorithms: SVM, Decision Trees.
3. Performance evaluation: confusion matrix, precision, recall, F1-score.
4. Exercises: model comparison, Scikit-learn usage.

Chapter 5: Unsupervised Learning

1. Clustering concepts.
2. Algorithms: K-means, DBSCAN.
3. 2D visualization and interpretation.
4. Exercises: apply clustering and visualize results.

Chapter 6: Neural Networks

1. Neural network architecture: perceptron, layers, hidden layers, weights, biases, activation functions (ReLU, Sigmoid, Softmax), exercises.
2. Introduction to Deep Learning: deep layers, convolutional networks (CNN).
3. Exercises: TensorFlow/PyTorch usage, dataset analysis, sentiment prediction.

Chapter 7: Mini Project (supervised personal work)
Create a complete classification or clustering model, including preprocessing, training, and visualization. Possible projects:

- Handwritten character recognition
- Natural disaster prediction
- Chatbot for frequent questions
- Machine sound anomaly detection
- Sentiment analysis on social media posts

Practical Works (PW):
PW 01: Initialization.
PW 02: Simple regression with Scikit-learn, visualization with Matplotlib.
PW 03: ML pipeline, data splitting, reinforce course concepts.
PW 04: Train a simple classification model with Scikit-learn.
PW 05: Apply clustering algorithm (K-means, DBSCAN), visualize clusters.
PW 06: Build a simple neural network with TensorFlow/PyTorch/Keras, build a simple CNN (e.g., MNIST dataset).

Assessment Method:
Final Exam: 60%, Continuous Assessment: 40%.

Bibliographic references
- Ganascia, J.Gabriel (2024) : l'IA expliquée aux humains. Paris France- Edition le Seuil.
- Anglais, Lise, Dilhac, Antione, Dratwa, Jim et al. (2023) : L'éthique au coeur de l'IA. Quebec Obvia.
- J.Robert (2024) : Natural Language Processing (NLP) : définition et principes – Datasciences. Lien : htPWs://datascientest.com/introduction-au-nlp-natural-language-processing
- Qu'est-ce que le traitement du langage naturel. Lien : htPWs://aws.amazon.com/fr/what-is/nlp/
- M.Journe : Eléments de Mathématiques discrètes – Ellipses
- F.Challet : L'apprentisage profond avec Python – Eyrolles
- H.Bersini (2024) : L'intelligence artificielle en pratique avec Python – Eyrolles
- B.Prieur (2024) : Traitement automatique du langage naturel avec Python – Eyrolles
- V.Mathivet (2024) : Implémentation en Python avec Scikit-learn – Eyrolles
- G.Dubertret (2023) : Initiation à la cryptographie avec Python – Eyrolles
- S.Chazallet (2023) : Python 3 – Les fondamentaux du langage - Eyrolles
- H.Belhadef, I.Djemal : Méthode TALN – Cours de l'unievrsité de Msila - Algérie

Semester: 2
Teaching Unit: UET 1.2
Subject 2: Compliance with Standards and Rules of Ethics and integrity
TWH: 45h00 (Lecture: 1h30)
Credits: 1
Coefficient: 1

Course Objectives:
Develop students' awareness of ethical principles and rules governing university life and the workplace. Raise awareness of respecting and valuing intellectual property. Explain the risks of moral misconduct such as corruption and how to combat them. Alert students to ethical issues raised by new technologies and sustainable development.

Recommended Prior Knowledge:
Ethics and professional conduct (fundamentals).

Course Content:

A. Respect for Ethics and Integrity

1. Overview of the MESRS Ethics and Professional Conduct Charter: Integrity and honesty, academic freedom, mutual respect, scientific truth requirement, objectivity and critical thinking, fairness, rights and obligations of students, teachers, and administrative/technical staff.
2. Responsible and honest research:

- Ethical principles in teaching and research.

- Responsibilities in teamwork: professional equality, anti-discrimination conduct, pursuit of general interest, inappropriate behaviors in collective work.
- Adopting responsible conduct and preventing misconduct: responsible conduct in research, scientific fraud, anti-fraud measures, plagiarism (definition, types, procedures to avoid unintentional plagiarism, detection, sanctions), data falsification and fabrication.

3. Ethics and professional conduct in the workplace:

- Legal confidentiality, company loyalty, responsibility within the organization, conflict of interest.
- Integrity: corruption at work, forms, consequences, prevention, and sanctions.

B. Intellectual Property
I. Fundamentals of Intellectual Property:

- Industrial property, literary and artistic property.
- Rules for citing references (books, scientific articles, conference papers, theses, dissertations, etc.).

II. Copyright:

- Copyright in the digital environment: databases, software, open-source software.
- Copyright on the Internet and e-commerce: domain names, intellectual property online, e-commerce sites, intellectual property and social networks.
- Patents: definition, rights, usefulness, patentability, filing in Algeria and worldwide.

III. Protection and Valorization of Intellectual Property:

- How to protect intellectual property, rights violation and legal tools, valorization, intellectual property protection in Algeria.

C. Ethics, Sustainable Development, and New Technologies:

- Link between ethics and sustainable development, energy saving, bioethics and emerging technologies (AI, scientific progress, humanoids, robots, drones, etc.).

Assessment Method:
Final Exam: 100%.

References:

1. Charte d’éthique et de déontologie universitaires, htPWs://www.mesrs.dz/documents/12221/26200/Charte+fran ais+d f.pdf/50d6de61-aabd-4829-84b3-8302b790bdce
2. Arrêtés N°933 du 28 Juillet 2016 fixant les règles relatives à la prévention et la lutte contre le plagiat
3. E. Prairat, De la déontologie enseignante. Paris, PUF, 2009.
4. Racine L., Legault G. A., Bégin, L., Éthique et ingénierie, Montréal, McGraw Hill, 1991.
5. Siroux, D., Déontologie : Dictionnaire d’éthique et de philosophie morale, Paris, Quadrige, 2004, p. 474-477.
6. Medina Y., La déontologie, ce qui va changer dans l'entreprise, éditions d'Organisation, 2003.
7. Didier Ch., Penser l'éthique des ingénieurs, Presses Universitaires de France, 2008.
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V- Detailed Program by Subject - Semester S3

Semester: 3
Teaching Unit: UEF 2.1.1
Subject 1: Foundation of modeling in Process Engineering
TWH: 45h00 (Lecture: 3h00, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Objectives:

Recommended Prior Knowledge:
Thermodynamics, kinetics, heterogeneous reactors, heat and mass transfer, fluid dynamics, numerical analysis.

Course Content:

1. Introduction
2. Definition of Modeling
3. Process Engineering Modeling
4. Steps in Modeling
5. Fundamental Modeling Laws in Process Engineering
   5.1 Continuity Equations
   5.1.1 Overall Continuity Equation
   - Applications: continuously stirred tank reactor (CSTR); plug flow reactor (PFR)

   5.1.2 Individual Continuity Equations
   - Applications: CSTR; PFR

   5.2 Energy Equation
   - Applications: CSTR with heat transfer device; PFR with heat transfer jacket

   5.3 Momentum Equation
   - Applications: laminar flow in vertical and horizontal pipes
6. Modeling Thermodynamic Phase Equilibria
   6.1 Phase Equilibrium Criteria
   6.1a Equations of State
   6.1b Activity Models
   - Liquid-liquid equilibrium
   - Vapor-liquid equilibrium
   - Solid-liquid equilibrium
7. Modeling Examples
   - Countercurrent packed extraction column
   - Plate distillation column
   - Trickling absorption column
   - Heat transfer in metallic sphere and cylinder
   - Modeling of liquid-liquid, vapor-liquid (low and high pressure), and solid-liquid equilibria

Lab Work (PW):
Solving models using Excel, COMSOL, MATLAB, etc.

Assessment Method:
Exam: 60%, Continuous Assessment: 40%

References:

- Transport Phenomena, by R. Byron Bird Warren E. *Stewart* Edwin N. *Lightfoot*, Second Edition;
- The Principles of Chemical Equilibrium , Kenneth Denbigh;
- Thermodynamics by Jean Vidal, Editions TECHNIP, 1997

Semester: 3
Teaching Unit: UEF 2.1.1
Subject 2: Refining and Petrochemicals Process
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Objectives:
Master the physical, thermal, and catalytic processes for the transformation and conversion of petroleum cuts into either final products or feedstocks for the petrochemical industry.

Recommended Prior Knowledge:
Thermodynamics, kinetics, heterogeneous reactors, heat and mass transfer, fluid dynamics.

Course Content:

Chapter 1: Refining Processes

- Schematic of a conventional refinery
- Evolution of refining: environmental and economic constraints
- Overview of refining processes
- Composition of crude oils and petroleum products
- Fractionation (TBP distillation) and characterization of crude oils and petroleum cuts
- Fractional distillation of crude oil (atmospheric and vacuum)
- Blending units (fuels, lubricants, etc.)
- Methods for calculating physical properties of hydrocarbons
- Standards and specifications
- Additives

Chapter 2: Petrochemical Processes

- Basic principles governing chemical transformation
- Industrial catalysts
- Property improvement processes: catalytic reforming, isomerization, etc.
- Conversion processes: steam cracking, catalytic cracking, etc.
- Finishing processes: hydrogenation, softening, etc.
- Environmental protection processes: flue gas treatment, wastewater treatment, etc.
- Hydrogen production (hydrogen in refinery, steam reforming, partial oxidation, hydrogen-energy coproduction)
- Different production schemes in petrochemistry
- Petrochemical products

Application: Refining and Petrochemical Processes – Mini Project

Assessment Method: Continuous Assessment: 40%; Exam: 60%

References:

[1]. Le pétrole : Raffinage et Génie Chimique. Tome 1 de J. P Wuithier. Publication de l'Institut Français du Pétrole. Edition Technip ; 01-1972

[2]. Pierre Leprince, Alain Chauvel, Jean-Pierre Catry et Lorraine Castex « Procédés de pétrochimie, caractéristiques techniques et économiques »,EditionsTechnip, 1971.
[3]. Robert A. Meyers: Handbook of Petroleum RefiningProcesses, Third Edition. © 2012 The McGraw-Hill Companies.
[4]. Handbook of Petroleum Processing - ISBN-13 978-1-4020-2820-5 (e-book). © 2008 Springer Science + Business Media B.V
[5]. J.-P. Wauquier , Collectif Technip – « Le raffinage du pétrole - Tome 1 - Pétrole brut - Produits pétroliers - Schémas de fabrication », Editeur : Technip, 1998
[6]. J.-P. Wauquier , Collectif Technip – « Le raffinage du pétrole -Tome 2 - Procédés de séparation, Editeur : Technip , 1998
[7]. P. Leprince, Collectif Technip – « Le raffinage du pétrole -Tome 3 - Procédés de transformation, Editeur : Technip, 1998
[8]. Jean-Pierre Favennec, Collectif Technip – « Le raffinage du pétrole -Tome 5 - Exploitation et gestion de la raffinerie, Editeur : Technip, 1998

Semester: 3
Teaching Unit: UEF 2.1.1
Subject 3: Process intensification
TWH: 22h30 (Lecture: 1h30)
Credits: 2
Coefficient: 1

Course Objectives:

1. Understand the principles of process intensification.
2. Apply intensification techniques to various processes.

Recommended Prior Knowledge:
Mass and heat transfer, catalysis, reactors, unit operations.

Course Content:

Chapter 1: Fundamentals of Process Intensification

- Definitions, principles, and applications of process intensification (PI)
- Implementation of process intensification: equipment-based and method-based approaches

Chapter 2: Equipment for Process Intensification

- Microreactors, oscillating baffle reactors, rotating disk reactors
- Centrifugal absorbers
- Rotating packed columns
- Application examples of these equipments in various processes

Chapter 3: Methods of Process Intensification

- Multifunctional reactors (reactive distillation, membrane reactors)
- Hybrid separations (membrane-absorption, membrane-distillation)
- Application examples of these methods

Chapter 4: Alternative Energy Sources

- Solar energy, ultrasound, microwaves

Chapter 5: Other Process Intensification Methods

- New solvents (supercritical fluids, ionic liquids)
- Application examples of these solvents

Assessment Method: Exam: 100%

References:

1. Stanckiewicz, A.,andMoulijn. Marcel Dekker, Re- engineering the Chemical Processing Plant-Process Intensification. Inc. N.Y 2003.

Semester: 3
Teaching Unit: UEF 2.1.2
Subject 1: Optimization Methods in Process Engineering
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Content:

1. **Introduction**
   1.1 Definition
   1.2 Examples of optimization in chemical engineering
   1.3 Importance of optimization in engineering
2. **Definition of an Optimization Problem**
   2.1 Review and definitions:

- Objective function / performance criterion
- Local and global extrema
- Gradients
- Hessian matrix
- Optimization constraints
  2.2 Properties of objective functions:
- Unimodal and multimodal functions
- Convex and concave functions

3. **Optimization for Single-Variable Functions without Constraints**

- Indirect methods: Newton, Quasi-Newton, Secant
- Direct methods: Equal intervals, Dichotomy, Fibonacci, Golden section
- Polynomial approximation methods: Quadratic and cubic approximations
- Davies-Swan-Campey method (successive evaluations)

4. **Optimization for Multivariable Functions without Constraints**

- Line search optimization
- Direct methods: Orthogonal directions method, Simplex method
- Indirect methods: Gradient method

5. **Constrained Optimization: Linear Programming**

- Definition
- Constraints and feasible region
- Graphical solution
- Analytical solution
  5.1 Examples

Assessment Method: Continuous assessment: 40%; Exam: 60%

References: Optimization of Chemical Processes, by Thomas F. *Edgar*, David M. *Himmelblau*.McGraw-Hill Chemical Engineering Series

Semester: 3
Teaching Unit: UEF 2.1.2
Subject 2: Multiphase Reactors
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Course Objectives:
Students will acquire knowledge regarding the operation of heterogeneous multiphase reactors such as absorbers, catalytic reactors, combustion reactors, and other two-phase heterogeneous reactors.

Recommended Prerequisites:
Basic knowledge of homogeneous reactors, chemical kinetics, and transport phenomena is recommended.

Course Content:
Chapter 1. Two-Phase Fluid-Fluid Reactors (6 weeks)
- Introduction
- Effect of chemical reaction on mass transfer (Two-film theory; pseudo-first-order reaction – Hatta number (Ha); fast reaction regime – Enhancement factor E; instantaneous reaction regime – E vs Ha diagram)
- Calculations for two-phase reactors (Batch reactors, Plug flow reactors, Continuous stirred-tank reactors)

Chapter 2. Catalytic Fluid-Solid Reactors (6 weeks)
- Intra-particle diffusion (Thiele modulus; effectiveness factor)
- Effectiveness and external mass transfer (Effect of catalyst particle size; External mass transfer)
- Influence of internal diffusion on reaction (Weisz-Prater criterion); Influence of external mass transfer on reaction (Mears criterion)
- Fixed-bed reactors; Fluidized-bed reactors

Chapter 3. Non-Catalytic Fluid-Solid Reactors (3 weeks)
- Shrinking core model

Assessment Method: Continuous assessment: 40%; Exam: 60%

References:

1. *Roustan M : Transfert gaz/liquide dans les procédés de traitement des eaux et des effluents gazeux, Tec § Doc Lavoisier, Paris (2003) ISBN : 2-7430-0605-6*
2. *Schweich D : génie de la réaction chimique, Tec ! Doc lavoisier(2001) ISBN : 2-7430-0459-2*
3. *R.Missen, C.Mims and B .Saville : Chemical reactions engineering and kinetics, John Wiley and Sons, new York (1999)*
4. *Levinspiel O : chemicalreaction engineering,3èmeédition, John Wiley and Sons, New York (1998) ISBN : 0471225424X*
5. *Villermaux J : Génie de la réaction chimique , conception et fonctionnement des réacteurs, 2ème édition, Tec § Doc Lavoisier , Paris (1993) ISBN : 2-85206-132-5*
6. *AtkinsonB and MayitunaF : Biochemical engineering and biotechnology hand book, Ed Mac Millan(1991) ISBN : 978-033342-4032*
7. *Froment G and Bischoff KB : Chemical reactor, analysis and design : John Wiley and Sons, New York (1979)*

Semester: 3
Teaching Unit: UEM 2.1
Subject 1: Process regulation and control
TWH: 45h00 (Lecture: 1h30, Tutorial: 1h00)
Credits: 4
Coefficient: 2

Course Objectives:
By the end of this course, the student should be able to master the control of a process and its implementation at the process scale.

Recommended Prerequisites:
Mathematics (differential equations, symbolic calculation, etc.), Electricity, Instrumentation.

Course Content:

Chapter 1. Linear Control Analysis of Continuous Systems (10 weeks)

- Introduction to control systems
- Mathematical review (ordinary linear differential equations, Laplace transforms)
- Mathematical modeling of chemical process examples
- Dynamic behavior analysis of first-order, second-order, and higher-order systems (phase lag, non-minimum phase, etc.)
- Stability analysis of a control system (Routh-Hurwitz criterion)
- Performance analysis (transient and steady-state response)
- Graphical analysis of system dynamics (Bode, Nyquist, and Black diagrams)
- Graphical stability analysis (gain and phase criteria)
- Root locus techniques for control analysis

Chapter 2. Linear Control Synthesis of Continuous Systems (3 weeks)

- Introduction to P and PI control, phase lead and phase lag

Chapter 3. Introduction to Adaptive and Predictive Control (2 weeks)

Assessment Method: Continuous assessment: 40%; Exam: 60%

References:

1. *Jean Pierre Corriou, Commande des procécédés, 3 éme édition Lavoisier, 2012.*
2. *Jean Pierre Corriou, Commande des procécédés, 2 éme édition Lavoisier, 2003.*
3. *George Stephanopoulos, Chemical Process ConytolAn Introduction to theory and Ptractice, Prentice/ Hall International, Inc, 1984.*

Semester: 3
Teaching Unit: UEM 2.1
Subject 2: Experimental design
TWH: 37h30 (Lecture: 1h30, PW: 1h00)
Credits: 3
Coefficient: 2

Course Objectives:
Enable students to master experimental manipulations and make results more meaningful.

Recommended Prerequisites:
Basic knowledge in mathematics.

Course Content:

Chapter 1: General Introduction and Factorial Designs

1. Introduction
2. What is an experimental design
3. Study domain and response surface
4. Factors
5. Concept of interaction
6. Model concept and multiple linear regression
7. Full factorial 2^k design
   7.1 Example of effect calculation
   7.2 Graphical representation of effects
   7.3 Matrix form – multilinear regression
8. Application example

Chapter 2: Significance Tests and Model Validation

1. Introduction
2. Experimental errors
3. Significance tests of effects
4. Confidence interval of model effects
5. Analysis of variance – validation of linear model
   5.1 ANOVA table
   5.2 Coefficient of determination – correlation coefficient
6. Application example

Chapter 3: Fractional Designs

1. Introduction
2. Design of a fractional plan
3. Analysis of fractional design
4. Application example
5. Other designs: Plackett-Burman and Taguchi designs

Chapter 4: Response Surface Designs

1. Introduction
2. Response surface concept and contour plots
3. Designs for second-degree model study
   3.1 Box-Behnken design
   3.2 Central composite design
4. Quality and optimality criteria of experimental designs
   4.1 Calculation of optimal designs
5. Application example of response surface designs

Chapter 5: Mixture Designs

1. Introduction
2. Geometric representation of mixtures
3. Study domain in mixture designs
4. Mathematical models of mixtures
5. Analysis of a mixture design
6. Application example
7. Mixture designs and experimental designs: combined designs

Applications:

- Introduction to Minitab software + obtaining coefficients of a full factorial plan and plotting main effects, interactions + ANOVA
- Fractional designs in Minitab
- Optimization using response surface designs (Box-Behnken + Central Composite)
- Use of mixture designs

Assessment Method: Continuous assessment: 40%; Exam: 60%

References:

Semester: 3
Teaching Unit: UEM 2.1
Subject 3: PW Refining and Petrochemicals process
TWH: 22h30 (PW: 1h30)
Credits: 2
Coefficient: 1

Course Objectives:

- Enable students to experimentally characterize a petroleum sample.
- Understand the operating principles and key characteristics of the instruments used.

Recommended Prerequisites:
Thermodynamics, kinetics, heterogeneous reactors, heat and mass transfer, fluid dynamics.

Course Content:

Refining and Petrochemistry
PW No. 1: Determination of flash point and flammability temperature of gas oil.
PW No. 2: ASTM distillation.
PW No. 3: Characterization of a petroleum sample by refractometry.
PW No. 4: Analysis of heavy petroleum products by infrared spectroscopy.
PW No. 5: Determination of cetane index and diesel index of a petroleum product.
PW No. 6: Determination of the aniline point of a petroleum product.
PW No. 7: Measurement of viscosity of petroleum products.

Assessment Method: Continuous assessment: 100%

Semester: 3
Teaching Unit: UET 2.1
Subject 1: Chemical reverse engineering
TWH: 67h30 (Lecture: 1h30, Tutorial or PW: 1h30)
Credits: 2
Coefficient: 2

Course Objectives:

- Train students in:
  • Competitive intelligence
  • Quality approach (product quality control from a supplier, traceability, conformity analysis)
  • Understanding/anticipation of various phenomena (premature aging, product reactivity, structure-property relationships)
  • Substitution of raw materials (shortage or strategic change)
  • Product optimization
  • Obtaining data for regulatory compliance
  • Intellectual property protection (checking patent infringement, unfair competition, etc.)

Recommended Prerequisites:
Physicochemical analysis methods (spectroscopy, microscopy, thermal analysis, etc.)

Course Content:

Chapter 1: Introduction to Chemical Reverse Engineering
1.1 History, legal and ethical issues

- Definitions and applications (materials, software, processes)
- Product design objectives, constraints, target market, product functionality
- How the product works and why it was designed this way

1.2 Methods and usage

- Chromatography: separate and identify mixture components
- Spectroscopy: identify and quantify chemical bonds and elements
- Microscopy: examine microstructure
- Thermal analysis: study thermal properties
- Rheology: study mechanical properties vs. time and temperature

1.3 Applications

- Polymers, paints, inks, powders, ceramics, composites, packaging
- Pharmaceuticals
- Food industry
- Cosmetics
- Petrochemicals

1.4 Cases where reverse engineering is not possible

- Complex formulations, lack of equipment, legal restrictions, safety issues, degradation

Chapter 2: General Methodology
2.1 Inverted pyramid approach

- Global product analysis: documentation and mixture overview
- Superficial analysis: solubility, chemical reactivity, fillers, number of components, molecular size
- Specific compound analysis: isolate and identify each species (chromatography, NMR, elemental analysis)
- Quantification: chromatographies, NMR, gravimetric techniques
- Application examples: epoxy resins, phenolic resins, paints, shampoos, medical devices

Chapter 3: Reverse Engineering Process
3.1 Hypothesis on manufacturing process

- Reconstruct steps from chemical composition (temperature, pressure, catalysts, addition order, purification)
  3.2 Modeling and simulation
- Use chemical simulation software (Aspen Plus, ChemCAD, etc.)
- Evaluate thermodynamic and kinetic equilibria
  3.3 Experimental reproduction
- Laboratory tests to verify formulation or process assumptions
- Parameter adjustments based on results
  3.4 Optimization
- Process improvement (yield, cost, environmental impact)
- Develop equivalent or improved formulations (generics, patentable alternatives)

Chapter 4: Development Techniques for Generic Pharmaceuticals

- Research and formulation
- Bioequivalence testing
- Toxicological, pharmacological, and clinical studies
- Marketing authorization (MA) process
- Quality control

Chapter 5: Polymer Development Techniques

- Sample acquisition and preparation
- Physical and chemical analyses (microscopy, spectroscopy, thermal analysis, etc.)
- Formulation and reconstruction
- Validation and optimization
- Advantages: product reproduction, improvement, new product development, cost reduction, competitor product understanding

Chapter 6: Reverse Engineering a Commercial Liquid Detergent

- Step 1: Sample collection
- Step 2: Physicochemical analysis (surfactants, polymers, additives)
- Step 3: Component quantification
- Step 4: Formulation hypothesis
- Step 5: Process reconstruction (cold mixing, solubilization, pH adjustment, additives)
- Step 6: Lab testing and adjustment (viscosity, foam, pH, stability)
- Step 7: Performance evaluation (cleaning power, stability, cost)

- Step 8: Final formulation optimization (biodegradable agents, fragrance, cost reduction)

Chapter 7: Analysis of Multigrade Engine Oil 5W-30

- Objective: understand chemical composition and technical properties to reproduce or improve a competitor lubricant
- Step 1: Sample preparation (new or used oil)
- Step 2: Physicochemical analysis (kinematic viscosity, VI, flash/freeze point, ICP-AES, FTIR, GC-MS)
- Step 3: Typical composition identification (base oil, ZDDP, Ca/Mg, P, viscosity modifiers, dispersants, corrosion inhibitors)
- Step 4: Formulation reconstruction
- Step 5: Validation tests (tribological, engine simulations, engine bench tests, catalyst compatibility)
- Result: 5W-30 engine oil compliant with API/ACEA, possibility of low SAPS formulation for Euro 6/7 vehicles

Assessment Method:

- Technical lab work: 30%
- Mini-project (report + presentation): 40%
- Final exam (MCQ + case study): 30%
- Overall: Exam 60%, Continuous assessment (PW): 40%

References:

- **Jacques Villermaux**, *Génie de la réaction chimique : conception et fonctionnement des réacteurs*, Éditions Tec & Doc, 1993.
- **Daniel Schweich**, *Génie de la réaction chimique*, Éditions Tec & Doc, 2001.
- **Gilbert F. Froment & Kenneth B. Bischoff**, *Chemical Reactor Analysis and Design*, Wiley, 2010.
- **Searson, D. P., Willis, M. J., & Wright, A.**, *Reverse Engineering Chemical Reaction Networks from Time Series Data*, 2014.
- **Marote, P., Martin, M., Bonhomme, A., Lantéri, P., & Clément, Y.**, *Artificial Intelligence for Reverse Engineering: Application to Detergents Using Raman Spectroscopy*, 2023.
- T**echniques de l'Ingénieur**, *Procédés chimiques : Dossier complet*.

Semester: 3
Teaching Unit: UET 2.1
Subject 2: Documentary research and thesis design
TWH: 22h30 (Lecture: 1h30)
Credits: 1
Coefficient: 1

Course Objectives:
Provide students with tools to efficiently search for relevant information for their final year project, guide them through the stages of scientific writing, emphasize the importance of communication, and teach rigorous and pedagogical presentation of their work.

Recommended Prerequisites:
Writing methodology, presentation methodology

Course Content:

Part I – Literature Research

Chapter I-1: Defining the Topic (2 weeks)

- Topic title
- List of keywords
- Gather basic information (specialized vocabulary, terminology, definitions)
- Identify required information
- Assess current knowledge in the field

Chapter I-2: Selecting Information Sources (2 weeks)

- Document types: books, theses, dissertations, journal articles, conference proceedings, audiovisual materials
- Resource types: libraries, internet
- Evaluate quality and relevance of sources

Chapter I-3: Locating Documents (1 week)

- Research techniques
- Search operators

Chapter I-4: Processing Information (2 weeks)

- Organize work
- Define initial questions
- Synthesize selected documents
- Establish links between sections
- Finalize research document structure

Chapter I-5: Bibliography Presentation (1 week)

- Bibliography formats: Harvard, Vancouver, mixed systems
- Document presentation
- Citation of sources

Part II – Thesis/Report Development

Chapter II-1: Structure and Steps of the Thesis (2 weeks)

- Define and delimit the topic (summary)
- Problem statement and objectives
- Additional sections: acknowledgements, abbreviations
- Introduction (written last)
- Literature review
- Hypotheses formulation
- Methodology
- Results
- Discussion
- Recommendations
- Conclusion and perspectives
- Table of contents
- Bibliography
- Appendices

Chapter II-2: Writing Techniques and Standards (2 weeks)

- Formatting: numbering chapters, figures, tables
- Cover page
- Typography and punctuation
- Scientific writing: style, grammar, syntax
- Spelling and language improvement
- Data saving, security, and archiving

Chapter II-3: Workshop – Critical Review of a Manuscript (1 week)

Chapter II-4: Oral Presentations and Defenses (1 week)

- Poster presentation
- Oral communication techniques
- Thesis defense

Chapter II-5: Avoiding Plagiarism (1 week)

- Citation and paraphrasing
- Complete bibliographic references
- Proper use of formulas, phrases, illustrations, graphs, and data

Assessment Method: Exam: 100%

References:

1. *. Griselin et al., Guide de la communication écrite, 2e édition, Dunod, 1999.*
2. *J.L. Lebrun, Guide pratique de rédaction scientifique : comment écrire pour le lecteur scientifique international, Les Ulis, EDP Sciences, 2007.*
3. *A.Mallender Tanner, ABC de la rédaction technique : modes d'emploi, notices d'utilisation, aides en ligne, Dunod, 2002.*
4. *M. Greuter, Bien rédiger son mémoire ou son rapport de stage, L'Etudiant, 2007.*
5. *M. Boeglin, lire et rédiger à la fac. Du chaos des idées au texte structuré. L'Etudiant, 2005.*
6. *M. Beaud, l'art de la thèse, Editions Casbah, 1999.*
7. *M. Beaud, l'art de la thèse, La découverte, 2003.*
8. *M. Kalika, Le mémoire de Master, Dunod, 2005.*