



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



Academic Master's Degree

Harmonised

National programme

Updated 2026

Field	Discipline	1Specialization
Science and Technomogy	Mechanical engineering	Renewable Energy in mechanic



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ماستر أكاديمي
مُوحَّد

برنامج وطني

تحيين 2026

التخصص	الفرع	الميدان
طاقات متجددة في الميكانيك	هندسة ميكانيكية	علوم وتكنولوجيا

Admission requirements

Field	Harmonised Master's degree	Bachelor's degrees giving access to the Master's degree	Ranking according to the compatibility of the bachelor's degree	Coefficient assigned to the bachelor's degree
Mechanical engineering	Renewable energies in mechanical engineering	Mechanical engineering	1	1.00
		Energy	1	1.00
		Energy physics (SM field)	2	0.8
		Materials Engineering	2	0.8
		Electromechanics	2	0.80
		Industrial maintenance	2	0.80
		Other licences in the ST field	5	0.60

Semester-based course organisation sheets for specialised subjects

Semester 1: Master's in Renewable Energy in Mechanical Engineering

Teaching unit	Subjects	Credits	Coefficient	Hours per week			Semester hours (15 weeks)	Additional work in Consultation (15 weeks)	Assessment method	
	Title			Course	Tutorial	Practical			Assessment Continuous	Examination
Fundamental EU Code: UEF 1.1.1 Credits: 10 Coefficients: 5	Advanced Fluid Mechanics	6	3	3 hours	1 hour 30 minutes		67	82 hours 30 minutes	40%	60
	Advanced Thermodynamics and Transport Phenomena	4	2	1.5 hours	1 hour 30 minutes		45	55 hours	40%	60
Fundamental EU Code: UEF 1.1.2 Credits: 8 Coefficients: 4	Renewable Resources and Meteorology	4	2	1 hour 30 minutes	1 hour 30 minutes		45 hours	55 hours	40%	60
	Applied Numerical Methods	4	2	1.5 hours	1 hour 30 minutes		45 hours	55 hours	40%	60
Methodological EU Code: UEM 1.1 Credits: 11 Coefficients: 7	Renewable Energies and Energy Issues	4	2	1.5 hours	1 hour 30 minutes		45 hours	55 hours	40%	60%
	TP Renewable Energy Sources and Meteorology	3	2			3 hours	37:30	37:30	100	
	Applied Numerical Methods Practical	2	1			1 hour 30 minutes	10:30 p.m.	27:30	100%	
	Advanced programming in Python	2	2	1 hour 30 minutes		1 hour 30 minutes	45 hours	55 hours	40%	60
Discovery EU Code: UED 1.1 Credits: 1 Coefficients: 1	Elective subject	1	1	1 hour 30 minutes			10:30 p.m.	2:30		100%
Total for the semester 1		30	17	12 0	7:30	7:00 a. m.	382 hours 30 minutes			

Semester 2: Master's Degree in Renewable Energy in Mechanical Engineering

Teaching unit	Subjects	Credits	Coefficient	Hours per week			Semester hours (15 weeks)	Additional work in Consultation (15 weeks)	Assessment method	
	Title			Course	Tutorial	Practical work			Continuous assessment	Examination
EU Fundamental Code: UEF 1.2.1 Credits: 10 Coefficients: 5	Solar radiation	4	2	1h30	1 hour 30 minutes		45 hours	55 hours	40%	60
	Advanced Heat Transfer and Transport Phenomena	6	3	3 hours	1 hour 30 minutes		67 hours 30 minutes	82 hours 30 minutes	40%	60%
EU Fundamental Code: UEF 1.2.2 Credits: 8 Coefficients: 4	Solar Thermal Energy and Applications	4	2	1.5 hours	1 hour 30 minutes		45 hours	55 hours	40%	60%
	Hydroelectric and wind energy	4	2	1 hour 30 minutes	1 hour 30 minutes		45 hours	55 hours	40%	60%
EU Methodological Code: UEM 1.2 Credits: 9 Coefficients: 5	Project design and sizing ER	3	2	1.5 hours		1 hour 30 minutes	37.5	37 hours 30 minutes	40%	60
	Conversion TP	2	1			1 hour 30 minutes	10:30 p.m.	27:30	100%	
	Thermal metrology, Servo control and Regulation	4	2	1 hour 30 minutes		1 hour 30 minutes	45 hours	55 hours	40%	60
Cross-disciplinary course Code: UE3 1.2 Credits: 2 Coefficients:	Compliance with ethical and integrity standards and rules	1	1	1.5			22:30	2:30		100%
	Elements of applied AI	2	2	1 hour 30 minutes		1 hour 30 minutes	45 hours	5 hours	40%	60%
Total semester 2		30	17	13	6	6	375 hours	375h00		

			0	0	0				
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Semester 3: Master's Degree in Renewable Energy in Mechanical Engineering

Teaching unit	Materials	Credits	Coefficient	Hours per week Weekly			Semester hours (15 weeks)	Additional work in consultation (15 weeks)	Assessment method	
	Title			Course	Tutorial	Practical work			Continuous assessment	Examination
Fundamental EU Code: UEF 2.1.1 Credits: 8 Weighting: 4	Working Fluids, Materials and Storage Devices	4	2	1.5 hours	1 hour 30 minutes		45 hours	55 hours	40%	60%
	Energy and Thermal Efficiency of Buildings	4	2	1.5 hours	1 hour 30 minutes		45 hours	55 hours	40%	60
Fundamental EU Code: UEF 2.1.2 Credits: 10 Coefficients: 5	Solar photovoltaics and applications	4	2	1.5 hours	1 hour 30 minutes		45 hours	55 hours	40%	60%
	Fuel cells and hydrogen production	4	2	1h30	1 hour 30 minutes		45 hours	55 hours	40%	60%
	Maintenance of renewable energy systems	2	1	1 hour 30 minutes			10:30 p.m.	27.5		100%
Methodological EU Code: UEM 2.1 Credits: 9 Coefficients: 5	Simulation and dimensioning software for renewable energy installations	2	1			1 hour 30 minutes	10:30 p.m.	27.5	100%	
	Cooling and solar air conditioning	1	1			1:30	3:00 p.m.	10:00	100%	
	Heat Exchangers	2	1	1:30			10:30 p.m.	27:30		100%
	Technical and Economic Study and Project Management ER	4	2	1 hour 30 minutes		1 hour 30 minutes	45	55 hours	40%	60
Cross-disciplinary EU Code: UET 2.1 Credits: 3 Coefficients: 3	Reserve engineering	2	2	1.5	1.5 hours workshop		45 hours	5:00	40%	60
	Documentary research and thesis design	1	1	1.5 hours			22:30	2:30		100%
Total for the semester 3		30	17	1:30 p.m.	6:00	6:00	382:30			

Discovery EU basket (S1, S2 and S3)

Important: The teaching team must decide on the choice of 06 UEDs before the start of the course, and must approve (formalise) its choice in a report signed by the head of department. This report must be sent to the various relevant bodies within the institution (VDP/VRP/diploma department, etc.).

1. Transfer techniques applied to drying^(*)
2. Marine Energy^(*)
3. Geothermal Energy^(*)
4. Aerodynamics and Turbomachinery^(*)
5. Research methodology (statistical methods, data processing, experimental design)^(*)
6. Inverse techniques^(*)
7. Water-Energy-Agriculture Nexus^(*)
8. Power Electronics ^(*)
9. ER Regulations and Standards^(*)
10. Photovoltaic materials
11. Solar Towers and Chimneys
12. Photovoltaic-Wind Hybrid System
13. CSP-gas hybrid systems
14. Optimisation, power control and grid injection techniques
15. Hybrid photovoltaic-thermal system
16. Solar-powered water desalination
17. Simulation software (COMSOL Multiphysics, Fluent, ANSYS, etc.)
18. Industrial ecology and sustainable development
19. Entrepreneurship
20. Energy audit

^(*) Recommended teaching units

Semester 4:

This semester is devoted to completing the Master's degree final project. It is carried out in a company or research laboratory (university or research centre). It is assessed by means of a dissertation and a viva voce examination.

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

This table is provided for information purposes only.

Evaluation of the Master's Degree Final Project

- Scientific value (Assessment by the jury) /6
- Thesis writing (Assessment by the jury) /4
- Presentation and response to questions (Assessment by the jury) /4
- Supervisor's assessment /3
- Presentation of the internship report (Assessment by the jury) /3

Detailed programmes by subject for semester S1

Semester: 1
Teaching unit: UEF 1.1.1
Subject 1: Advanced Fluid Mechanics VHS: 67.5 hours (Lectures: 3 hours, Tutorials: 1.5 hours)
Credits: 6
Coefficient: 3

Course objectives:

The aim of the course is to develop students' basic knowledge. The energy specialisation is closely linked to the phenomenology of viscous and turbulent flows observed in energy systems, and understanding and analysing them is essential. Familiarising students with the physical and mathematical laws and models of these often complex flows is one of the fundamentals of the specialisation in acquiring the consistent teaching necessary for research.

Recommended prior knowledge:

- Basic fluid mechanics
- Mathematics
- Numerical methods

Course content:

- Chapter 1: Fluid dynamics and transport equations** (3 weeks)
 Description of motion, tensors, particle derivative, transport of an infinitesimal volume, mass, momentum and energy balance, viscous fluids, Navier-Stokes equations, elements of rheology
- Chapter 2: Ideal fluids and their applications** (2 weeks)
 Potential flows, interface waves
- Chapter 3: Dynamics of real fluids** (2 weeks)
 Unidirectional flows, Stokes flow, low-speed flow, low Reynolds number flow, hydrodynamic lubrication, etc.
- Chapter 4: Boundary layers** (2 weeks)
 Boundary layer development, approximate solutions, Van Karman equation, etc.
- Chapter 5: Turbulent flows** (2 weeks) Average field and fluctuations, Reynolds equations, Boussinesq model, Prandtl mixing length model, turbulence scales, $K-\epsilon$, $K-\omega$, SST turbulence models
- Chapter 6: Calculation of Flows in Pipes** (4 weeks) Flow of incompressible fluids in pressurised pipes: linear pressure losses. Use of Moody diagrams.
- Flow in singularities: singular pressure losses. Borda's theorem
 - Calculations and dimensioning of hydraulic networks
 - Introduction to one-dimensional flows of compressible fluids
 - Introduction to free surface flows

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

- 1-Inge L. Ryhming, *Fluid Dynamics*, Presse Polytechniques et Universitaire Romandes. 2-P. Chassaing, *Turbulence in Fluid Mechanics*, CEPADUES– Editions.
- 3-R. Comolet, *Experimental Fluid Mechanics, Volume II, Real Fluid Dynamics, Turbomachinery*, Editions Masson, 1982.
- 4-T. C. Papanastasiou, G. C. Georgiou and A. N. Alexandrou, *Viscous Fluid Flow*, CRC Press LLC, 2000.
- 5-Adil Ridha, *Course on Real Fluid Dynamics, M1 Mathematics and Applications: Mechanics Specialisation*, University of Caen, 2009.
- 6-R. W. Fox, A. T. Mc Donald and P. J. Pritchard, *Introduction to Fluid Mechanics*, sixth edition, Wiley and Sons editor, 2003.
- 7-Hermann Schlichting, *Boundary Layer Theory*, McGraw Hill Book Company.
- 8-W.P. Graebel, *Advanced Fluid Mechanics*, Academic Press 2007.
- 9-H. Tennekes and J. L. Lumley, *A First Course in Turbulence*, The MIT Press, 1972.
- 10- B. R. Munson, *Fundamentals of Fluid Mechanics*, 6th Edition, Wiley and Sons Editor, 2009.

Semester: 1

Teaching unit: UEF 1.1.1

Subject 2: Advanced Thermodynamics VHS: 45 hours

(Lectures: 1 hour 30 minutes, Tutorials: 1 hour 30 minutes)

Credits: 4

Coefficient: 2

Teaching objectives:

Modern thermodynamics is both a branch of science and engineering. Scientists are generally interested in gaining a fundamental understanding of the chemical and physical aspects of fixed quantities of matter, and use the principles of thermodynamics to identify the various relationships between the properties of matter (pressure, internal energy, specific heat, etc.). Engineers are more interested in studying systems and their interactions with their immediate environments. To account for all of this, thermodynamics has naturally been extended to the study of the systems through which matter moves, which of course includes renewable energy conversion systems. The programme consists of nine chapters, which will cover the first and second laws of thermodynamics, steam and gas cycles, the optimisation of energy systems through exergy analysis, and the new concept of entransy proposed by Guo.

Recommended prior knowledge:

Thermodynamics and mathematics at bachelor's degree level in an engineering specialisation.

Course content:

Chapter 1: Introduction

(1 week)

Thermodynamics, use, importance, definition of a thermodynamic system, specific volume and pressure, temperature.

Chapter 2: Energy and the First Law of Thermodynamics

(1 week)

Concepts of energy in mechanics, work, energy, heat transfer, energy balance for a closed system, energy analysis of cycles.

Chapter 3: Evaluation of Properties (2 weeks)

Thermodynamic State of a System, the $p-v-T$ Relationship, Thermodynamic Properties, Generalised Compressibility Diagram, Internal Energy, Enthalpy, and Specific Heats of an Ideal Gas, Polytropic Process of an Ideal Gas.

Chapter 4: Energy and Analysis by Control Volume

(1 week)

Conservation of Mass in a Control Volume, Conservation of Energy in a Control Volume, Analysis of a Control Volume in Steady State, Transient Analysis.

Chapter 5: The Second Law of Thermodynamics

(2 weeks)

Introduction to the Second Law of Thermodynamics, Identification of Irreversibilities, Application of the Second Law to Thermodynamic Cycles, Maximum Performance of a Cycle Operating between Two Heat Reservoirs, The Carnot Cycle.

Chapter 6 Entropy**(2 weeks)**

Introducing Entropy, Definition of Entropy Change, Use of Data for Entropy from Thermodynamic Tables, Entropy Change in an Internal and Reversible Process, Entropy Balance for Closed Systems, Entropy Balance of a Control Volume, Isentropic Process, Isentropic Efficiency of Turbines, Nozzles, Compressors and Pumps, Heat Transfer and Work of a Reversible Process such as Internal Flow in Steady State.

Chapter 7 Exergy Analysis and Entransy**(2 weeks)**

Introduction to Exergy, Definition of Exergy, Exergy Balance for a Closed System, Exergy Flow, Exergy Balance of a Control Volume, Exergy Efficiency and the Second Law, A New Concept for Optimising Energy Systems: Entransy, Bejan's Paradox and Guo's Concept of Entransy.

Chapter 8 Steam Power Plants**(2 weeks)**

Modelling of Steam Power Plants, Analysis of Steam Power Plants—Rankine Cycle, Performance Improvement—Superheating and Reheating, Performance Improvement—Steam Regeneration Cycles, Other Aspects of Steam Cycles, The Kalina Cycle.

Chapter 9 Gas Power Plants**(2 weeks)**

Modelling Gas Power Plants, The Air Brayton Cycle, Gas Turbine with Regeneration Combined Cycle Gas Turbine—Steam Cycle, Ericsson and Stirling Cycles

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

1. *Thermodynamics: An Engineering Approach*, Yunus Cengel and Michael Boles, 8th Edition, McGraw-Hill, 2015.
2. *Advanced Thermodynamics for Engineers*, D. E. Winterbone and A. Turan, 2nd Edition, Elsevier, 2015.
3. *Advanced Engineering Thermodynamics*, Adrian Bejan, 3rd Edition, John Wiley and Sons, 2006.
4. *Fundamentals of Engineering Thermodynamics*, M. J. Moran and H.N. Shapiro, 8th Edition, John Wiley and Sons, 2015.
5. *Applied Thermodynamics*, Gordon Van Wylen and Richard Sontag, Erpi Edition, 2002.
6. *Applied Thermodynamics: 80 exercises and 25 solved problems*, Chantal Sèdes and Henri Guénoche, Masson Edition.

Semester: 1

Teaching unit: UEF 1.2.1

Subject 2: Advanced Heat Transfer and Transport Phenomena VHS: 45 hours (Lectures: 3 hours, Tutorials: 1.5 hours)

Credits: 4

Coefficient: 3

Course objectives:

Thermodynamics, with its various principles, allows us to calculate the amounts of energy involved in the transformation from one state of equilibrium to another. However, it provides no information on the nature of these transformations or on the methods used to quantify them. The advanced heat transfer course, based on the first and second principles of thermodynamics, will answer all these questions. Its ultimate goal is to provide a broad overview of all the phenomena and mechanisms of heat transfer (except radiation, which, due to its importance for the speciality, will be covered in a module devoted entirely to it). The different modes of heat transfer are presented, namely steady-state and unsteady-state conduction, forced convection and natural convection, as well as heat transfer by phase change (evaporation and condensation). The course, with its tutorials, provides both a description of the phenomena and mechanisms involved and the basic methods for quantifying them, based on analytical approaches, dimensional analysis and similarity (the numerical approach, which is widely used but covers a vast amount of content, is dealt with separately in another module).

Recommended prior knowledge:

Theoretical physics - Thermodynamics - Fluid mechanics - Differential calculus and integrals

Course content:

Chapter 1: General Information on Heat Transfer

(1 week)

Introduction, Definitions - Formulation of a heat transfer problem: energy balance - expression of energy flow

Chapter 2: Heat Transfer by Conduction in Steady State (2 weeks)

Heat equation - Unidirectional transfer: wall and multi-layer hollow cylinder - consideration of radiative transfers -

Multidirectional transfer: Shape coefficient method - Numerical methods - Fins: flow extracted by a fin - fin efficiency - choice of fins

Chapter 3: Heat Transfer by Conduction in Variable Conditions (3 weeks)

Unidirectional conduction in variable conditions: medium at uniform temperature – unidirectional transfer in limited media – complex systems: quadrupole method – Unidirectional conduction in variable conditions with change of state –

Multidirectional conduction under variable conditions

Chapter 4: Heat Transfer by Forced Convection

(4 weeks)

Review of dimensional analysis - Convection without change of state: General information and definitions - Expression of heat flux, convection boundary layers (velocity boundary layer, thermal boundary layer), local and average convection coefficients, derivation of convective heat transfer equations, Nusselt number, external flow (empirical method: plate, cylinder and sphere, flow through a tube bundle), Internal flow (hydrodynamic considerations, thermal considerations, energy balance, laminar flow in a circular tube, correlations for: turbulent flow in a circular tube, non-circular and annular tubes).

Chapter 5: Heat Transfer by Free (Natural) Convection

(3 weeks)

Physical considerations of the problem, Grashof and Rayleigh numbers, Laminar free convection on a vertical flat surface, effects of turbulence, empirical correlations: external free convection flow (plate, cylinder, sphere), free convection between two parallel flat plates, cavities (rectangular cavities, concentric cylinders and spheres), mixed forced and free convection.

Chapter 6: Heat Transfer by Boiling and Condensation

(2 weeks)

Dimensionless numbers in boiling and condensation, boiling in vessels, boiling correlations, condensation: laminar film boiling on a vertical plate, film condensation on tubes and spheres, film condensation on horizontal tubes.

Assessment method:

Continuous assessment: 40%; Examination: 60%.

Bibliographical references:

- 1- J.F. SACADURA, "Initiation aux Transferts Thermiques" (Introduction to Heat Transfer), CAST technique et documentation, 1978.
- 2- F. KREITH, "Heat Transfer and Thermodynamics", translation, Masson, 1967.
- 3- Mc. ADAMS, "Principles of Heat Transfer", Mc GRAW-HILL, 1989.
- 4- J. P. HOLMAN, "Heat Transfer", McGraw-Hill 7th Edition, 1992
- 5- FRANK P. INCROPERA, "Introduction to Heat Transfer", John Willey & Sons; 3rd edition, 1996.
- 6- Yunus A. Cengel and F. Ghajar, Heat and Mass Transfer: Fundamentals and Applications, 5th Edition, McGraw-Hill, 2014.
- 7- Exercices on heat transfer, M. F. MARINET et al., course document ENSHMG – Grenoble – France, 1984.
- 8- Heat Transfer, Volume 1: Principles, J. CRABOL, Edition Masson, 1990.
- 9- Heat Transfer, Volume 2: Industrial Applications, J. CRABOL, Masson Publishing, 1990.
- 10- Heat Transfer, Volume 3: Problem Solutions, J. CRABOL, Masson Publishing, 1992.
- 11- Lectures and Basic Data – Heat Transfer – Anisothermal Fluid Mechanics, J. Taine et J. P. PETIT, Dunod Publishing – Paris, 1995.
- 12- Holman J.P., "Heat Transfer", seventh edition, Mac Graw Hill, 1990.
- 13- Özisik M. N., "Heat conduction", John Wiley & Sons, Inc., 1993.

Semester: 1

Teaching unit: UEF 1.1.2

Subject 3: Renewable Energy Sources Meteorology VHS: 45 hours

(Lectures: 1 hour 30 minutes, Tutorials: 1 hour 30 minutes)

Credits: 4

Coefficient: 2

Teaching objectives:

Acquire a good understanding of the scientific and technical aspects of assessing the potential of renewable energies.
Become familiar with the tools used to assess energy resources, in particular instruments for measuring climatological data in a weather station, etc.

Recommended prior knowledge:

Bachelor's degree level and programme in an engineering specialisation.

Course content:

Chapter 1: Solar electricity conversion (2 weeks)

- Photovoltaic cell and module technologies
- Photovoltaic system technologies
- Tools for measuring and evaluating solar resources

Chapter 2: Solar thermal conversion (3 weeks)

- Low-temperature solar technologies
- Solar concentration technologies
- High-temperature solar technologies

Chapter 3: Wind turbine technologies (2 weeks)

- Assessment of wind resources (global distribution and distribution in Algeria)
- Wind meteorology, atmospheric stability
- Variation in wind speed with height
- Statistical distribution of wind speed
- Wind speed measurements
- Wind system technologies

Chapter 4: Geothermal Resources (2 weeks)

- Resources
- Conversion technologies

Chapter 5: Hydraulic power (2 weeks)

- Resources
- Conversion Technologies

Chapter 6: Biomass (2 weeks)

- Resources
- Biogas Fermentation,
- Biofuel (sugar cane, cereals, beetroot).
- Electricity through direct combustion,

Chapter 7: Solar hydrogen (2 weeks)

Recommendations:

- * **Seminar:** State of the art in renewable energy technologies and solar resource assessment techniques
- *- **Visit:** to a solar PV, wind or solar-gas hybrid power plant.

Assessment method:

Continuous assessment: 40%; Examination: 60%.

Bibliographical references:

- 1- Ahmed F. Zobar, Ramesh Bansal, "Handbook of Renewable Energy Technology", World Science (2011).
- 2- Henrik Lund, Renewable Energy Systems, Academic Press (2010).
- 3- Solar Energy. Calculation and Optimisation - Energy Engineering, Jacques Bernard, Publisher: Ellipses, 2004.
- 4- Solar Energy Resources: Assessment of Energy Resources, Christian Perrin de Brichambaut, Publisher: Tech. & Doc. / Lavoisier, 1999.
- 5- Solar Energy Engineering: Processes and Systems, Soteris A. Kalogirou, Publisher: Academic Press Inc 2009.
- 6- D. P. Kothari, K. C. Singal and Rakesh Ranjan, Renewable Energy Sources and Emerging Technologies, PHI Lear. Priv. Ltd (2008).
- 7- J. Duffie, and W. Beckman: Solar Engineering of Thermal Processes, John Wiley & Sons, New York, 1991.
- 8- Charles Wereko-Brobby: Biomass Conversion and Technology, John Wiley & Sons, 1996.
- 9- B. H. Khan, Non-Conventional Energy Resources, McGraw Hill, 2nd edition, 2009.
- 10- Heliothermal: Solar resources, methods and calculations, Pierre-Henri Communay, GRE Publishing, 2002.
- 11- Solar radiation in the terrestrial environment Alain Chiron de la Casinière, Publisher: Publibook, 2003.

Semester: 1

Teaching unit: UEF 1.1.2

Subject 4: Applied numerical methods VHS: 45 hours

(Lectures: 1.5 hours, Tutorials: 1.5 hours)

Credits: 4

Coefficient: 2

Course objectives:

Students will acquire the skills necessary to digitally model transport phenomena in the field of renewable energy. Modelling is based on numerical discretisation methods with a view to gaining a better understanding of fluid flow phenomena coupled with heat and mass transfer.

Recommended prior knowledge:

- Knowledge of fluid mechanics and heat and mass transfer,
- Mathematical analysis,
- Numerical analysis,
- Computer programming languages.

Course content:

Chapter 1: Study methods and mathematical description of transport phenomena	(2 weeks)
Chapter 2: Main numerical discretisation methods	(2 weeks)
Chapter 3: Diffusion and radiation problems	(3 weeks)
Chapter 4: Convection-diffusion problems	(3 weeks)
Chapter 5: Flow field calculation	(2 weeks)
Chapter 6: Applications in the field of renewable energies	(3 weeks)

Assessment method:

Continuous assessment: 40%; Examination: 60%.

Bibliographical references:

- 1- Patankar, *Numerical heat transfer and fluid flow*, McGrawHill, Hemisphere, Washington, D.C, 1980.
- 2- H.K. Versteeg et W. Malalasekera, *An introduction to computational fluid dynamics. The Finite volume method*, Longman scientific & technical, London, 1995.
- 3- V. R. Voller, *Basic Control Volume Finite Element Methods for Fluids and Solids*, World Scientific Publishing Co. Pte. Ltd., Singapore, 2009.
- 4- Joe D. Hoffmann, "Numerical Methods for Engineers and Scientists", 2nd Ed., McGraw-Hill, New York, 2001.
- 5- Chapra, S. C., and Canale, R. P., "Numerical Methods for Engineers", 3rd Ed., McGraw-Hill, New York, 1998.
- 6- Aslak Tveito and Ragnar Winther, *Introduction to Partial Differential Equations: A Computational Approach*, Springer-Verlag, New York, 1998.

- 7- Y. Pinchover and J. Rubinstein, *An Introduction to Partial Differential Equations*, Cambridge University Press, 2005.
- 8- Richard Hyberman, *Elementary Applied Partial Differential Equations*, 2nd Ed., Prentice Hall, USA, 1983.
- 9- Klauss A. Hoffmann, Steve T. Chiang, *Computational Fluid Dynamics*, 4th ed., Engineering Education System, USA, 2000.
- 10- William F. Ames, *Numerical Methods for Partial Differential Equations*, 2nd Ed., Academic Press, USA, 1977.
- 11- Joe D. Hoffmann, *Numerical Methods for Engineers and Scientists*, 2nd Ed., McGraw-Hill, New York, 2001.
- 12- Chapra, S. C., and Canale, R. P., *Numerical Methods for Engineers*, 3rd Ed., McGraw-Hill, New York, 1998.

Semester: 1

Teaching unit: UEM 1.1

Subject 1: Renewable Energies and Energy Issues VHS: 45 hours (Practical work: 3 hours)

Credits: 4

Coefficient: 2

Teaching objectives:

Students (who have chosen this research specialisation) will be able to become specialists or experts in this field, enabling them to develop projects for the country and the region concerning the design and implementation of highly energy-efficient systems powered by renewable energy sources.

Recommended prior knowledge:

Bachelor's Degree Programme in Fluid Mechanics. Fundamental Thermodynamics. Heat Transfer. Environmental Characteristics. Different Types of Energy. Concepts of General Chemistry

Course content:

Chapter 1: Development of renewable energies and materials	(2 weeks)
Chapter 2: Energy challenges	(2 weeks)
Chapter 3: Environmental issues	(2 weeks)
Chapter 4: Policy issues	(2 weeks)
Chapter 5: Employment issues	(2 weeks)

Assessment method:

Continuous assessment: 100 %

Bibliographical references:

1. *Renewable energies: current situation and prospects* By Claude Acket, Jacques Vaillant. 2011
2. *Pascale GILLON, Energy: challenges and prospects*, CNRS online course, March 2013.
3. *Michel JEHAN, Hydrogen for Renewable Energy*, online presentation, McPhyEnergy S.A., 21 March 2012.
4. *Manual on Energy Statistics*, International Energy Agency, OECD/IEA, 2005.
5. *Bent Sørensen, Renewable Energy*, Elsevier Academic Press, Third Edition (2005-) Documentation from the Algerian Ministry of Energy.
6. *United Nations documentation on the environment and climate change*.

Semester: 1

Teaching unit: UEM 1.1

Subject 2: Practical work on renewable resources and meteorology VHS: 37

hours 30 minutes (practical work: 2 hours 30 minutes)

Credits: 4

Coefficient: 2

Teaching objectives:

The development of solar or wind maps would be of great importance, especially when carried out over a typical year. A typical year is a file of climate data relating to a year, sometimes real but more often artificial, consisting of actual months, representative of the average climate of a site. This file is used as input for a simulation programme to evaluate the thermal balance of a system or simply to analyse its operation and evolution.

Recommended prior knowledge:

Bachelor's degree programme in Fluid Mechanics. Fundamental Thermodynamics. Heat Transfer. Environmental Characteristics. Different Types of Energy. Concepts of General Chemistry

Course content

Chapter 1	General information	(3 weeks)
	<ul style="list-style-type: none"> - Solar radiation (global, diffuse, direct) - Renewable energy conversion 	
Chapter 2	Solar energy sources	(4 weeks)
	<ul style="list-style-type: none"> - Experimental implementation - Preparation of thermocouples - preparation of the pyranometer - description of the prototype - global solar radiation calculation - evolution of global solar radiation 	
Chapter 3	Wind energy resources	(4 weeks)
	<ul style="list-style-type: none"> - atmospheric conditions - wind speed distribution models - Climatological data and buildings 	
Chapter 4	Geothermal energy deposits	(4 weeks)
	<ul style="list-style-type: none"> - principle of operation and use of geothermal energy - low and medium temperature geothermal energy - horizontal collectors - vertical geothermal probes - other uses of geothermal energy - high-energy geothermal energy 	
Chapter 5	Methods used for selecting the year energy deposit	(2 weeks) type of

Assessment method:

Continuous assessment: 100%;

Bibliographical references:

1. *Evaluation of Renewable Energy Sources*. Rachid Chriqi. 2011.
2. *Energy systems: energy supply and demand: methods of analysis*, Pierre Verstraete, Gérard Sarlos, Pierre-André Haldi.
3. *Renewable energies*, Jacques Vernier.
4. *Renewable energies: common misconceptions about renewable energies*, Francis Meunier.
5. *Renewable energies: current situation and prospects*, Jacques Vaillant.

Semester: 1
Teaching unit: UEM 1.1
Subject 3: Practical work Applied numerical methods VHS: 22.5
hours (practical work: 1.5 hours)
Credits: 3
Coefficient: 2

Course objectives:

Students will acquire the skills necessary to digitally model transport phenomena in the field of renewable energies. Modelling is based on numerical discretisation methods with a view to gaining a better understanding of fluid flow phenomena coupled with heat and mass transfer.

Recommended prior knowledge:

- Knowledge of fluid mechanics and heat and mass transfer,
- Mathematical analysis,
- Numerical analysis,
- Computer programming languages.

Course content:

- TP1: Diffusion and radiation problems **(3 weeks)**
- TP2: Convection-diffusion problems **(3 weeks)**
- TP3: Flow field calculation **(3 weeks)**
- TP4: Applications in the field of renewable energies **(3 weeks)**
- **Other (depending on available resources)** **(3 weeks).**

Assessment method:

Continuous assessment: 100%.

Bibliographical references:

- 1- I.S.V. Patankar, *Numerical heat transfer and fluid flow*, McGraw-Hill, Hemisphere, Washington, D.C., 1980.
- 2- H.K. Versteeg & W. Malalasekera, *An introduction to computational fluid dynamics. The Finite volume method*, Longman scientific & technical, London, 1995.
- 3- V. R. Voller, *Basic Control Volume Finite Element Methods for Fluids and Solids*, World Scientific Publishing Co. Pte. Ltd., Singapore, 2009.
- 4- Joe D. Hoffmann, "Numerical Methods for Engineers and Scientists", 2nd Ed., McGraw-Hill, New York, 2001.
- 5- Chapra, S. C., and Canale, R. P., "Numerical Methods for Engineers", 3rd Ed., McGraw-Hill, New York, 1998.
- 6- Aslak Tveito and Ragnar Winther, *Introduction to Partial Differential Equations: A Computational Approach*, Springer-Verlag, New York, 1998.
- 7- Y. Pinchover and J. Rubinstein, *An Introduction to Partial Differential Equations*, Cambridge University Press, 2005.
- 8- Richard Hyberman, "Elementary Applied Partial Differential Equations", 2nd Ed., Prentice Hall, USA, 1983.
- 9- Klaus A. Hoffmann, Steve T. Chiang, "Computational Fluid Dynamics", 4th ed., Engineering Education System, USA, 2000.
- 10- William F. Ames, "Numerical Methods for Partial Differential Equations", 2nd ed., Academic Press, USA, 1977.

Semester: S1

Teaching unit: UET 1.1.1

Subject: Advanced Programming in Python VHS: 45 hours (1.5-hour lectures, 1.5-hour practical sessions)

Credits: 2

Coefficient: 2

Course objectives:

Targeted skills:

- Use of IT tools for the acquisition, processing, production and dissemination of information
- Python and project management skills
- Skills in automation and data visualisation.

Objectives:

- To deepen students' mastery of the Python language and introduce them to the basics of data analysis and artificial intelligence.
- Acquire a solid foundation in computer science.
- Learn to programme in Python and Excel.
- Master task automation
- Master project management software

Required equipment:

- A computer with Python installed.
- Python libraries: NumPy, Pandas, Scikit-learn, Matplotlib, os.listdir, os.path.exists, os.mkdir, os.rmdir, Matplotlib, Seaborn, Plitly, Request, Beautiful Soup, Tkinter, PyQt, etc.
- Tensorflow, PyTorch.

Prerequisites: Python programming.

Course content:

Chapter 1: Review of Python programming

(2 weeks)

1. Introduction: Basic concepts in computer science and digital tools, installing Python.
2. Introduction to the concept of operating systems: roles, types (Linux, Windows, etc.), priority management,
3. Introduction to computer networks (principles, IP addresses, DNS, internet, etc.)
4. Basic programming: Interactive mode and script mode, variables, data types, operators. Conditional structures and loops (if, for, while).
5. Functions and essential elements: Predefined functions and function creation. Standard modules (math, random). Character strings, lists, basic data manipulation.
6. Files, lists, tuples, dictionaries
7. Exercises:
 - Python learning 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: working with Excel or CSV files
 - Definitions and examples of automation (sending emails, etc.)
2. File manipulation with Python:
 - Using libraries to:

- ✓ Browsing a folder (os.listdir)
- ✓ Checking whether a file or folder exists (os.path.exists)
- ✓ Creating or deleting folders (os.mkdir, os.rmdir)
- ✓ Visualising data: Matplotlib, Seaborn, Plitly
- ✓ Request to respond with Application Programming Interfaces (APIs)
- ✓ Beautiful Soup for data scraping
- ✓ Tkinter, PyQt for visualising graphical data
- Copying or moving files with shutil...
- Searching, sorting, and generating simple reports.
- Serialisation and deserialisation (using the pickle module).
- Serialisation of objects and processing of large files (streaming).
- ...

3. Exercises:

- Using openpyxl and pandas to read, modify and write Excel or CSV files to:
 - ✓ Creating automatic reports
 - ✓ Automatically extract data
 - ✓ ...
- Scripting for:
 - ✓ processing text files (searching, sorting)
 - ✓ automating technical calculations
 - ✓ managing simple reports (PDF, Excel)
 - ✓ ...
- Sorting, search and insertion sort algorithms
- Implement a search function in a list.
- File operations
- Secure browsing (simple network configuration, password management)
-

Chapter 3: Advanced Excel training

(2 weeks)

1. Macro principles and creating a simple macro,
2. Pivot tables,
3. Histograms,
4. Bar charts,
5. Spider charts,
6. Etc.
7. Excel exercises ...

Chapter 4: Learning GanttProject

(2 weeks)

1. Introduction to project management:
 - What is a project?
 - What are the challenges of managing a project?
 - GanttProject interface
2. Tasks (creation, modification, organisation)
3. Time management (project start and end dates)
4. Resource management
5. Exercises on Gantt Project

Chapter 5: Advanced object-oriented programming

(3 weeks)

1. Code organisation:
 - Custom functions, parameters, return values.
 - Modules, imports, and packages.
2. Complex data structures:
 - Lists, tuples and dictionaries: creation, modification, deletion, traversal.
3. Fundamental concepts of object-oriented programming (OOP):

- Classes, objects, attributes and methods.
 - Public, private and 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 AI

(2 weeks)

1. Introduction to common datasets in AI:
 - Iris, MNIST, CIFAR-10, Boston Housing, ImageNet.
2. Data pre-processing for machine learning:
 - Cleaning, normalisation, encoding, data separation.
 - Cross-validation.
3. Feature engineering techniques:
 - Selection, feature creation, dimension reduction.
4. Essential libraries for AI model development:
 - scikit-learn, TensorFlow, Keras, PyTorch

5. Practical

exercises:

TP 01: Mastering the basics of Python programming

(Control structures, types, loops, simple functions)

1. Introduction
2. Reading and processing text files
3. Managing simple reports (PDF, Excel)

Practical assignment 02:

Develop specifications for a mini task automation project using Python, consisting of automatically identifying and sending reports by email using Python:

1. Load data from a file (e.g. experimental measurements),
2. Perform simple statistics on the data (mean, standard deviation with interpretation),
3. Generate a graph,
4. Send the result using Python.

TP 03:

1. Programming the dashboard seen in class using Excel
2. Creating automated Excel tables
3. Simple macros,
4. Conditional formulas,
5. V lookup.

Practical work 04:

Organising a meeting in Ganttproject

1. Create a new project:
 - Project name: "Meeting ..."
 - Start date: Date and time of the meeting
 - Estimated duration: total duration of the meeting
2. Definition of tasks
 - Agenda items (each agenda item becomes a task)
 - Sub-tasks: If an item is complex, create the corresponding sub-tasks
 - Initial and final tasks (e.g. "Welcome participants", "Close the meeting")
3. Definition of resources:

- Participants (each participant is a resource)
 - Equipment (computer, data projector, etc.)
4. Estimated duration:
 - Duration of each item: time required for each item on the agenda
 - Transition time from one item to the next
 5. Creating the Gantt chart:
 - Viewing the agenda
 - Identify key items
 6. Monitor progress in real time (Gantt chart projection)

TP 05: Advanced structures and code organisation*(Custom functions, dictionaries, modules and modular organisation)***TP 06: Advanced object-oriented programming in Python***(Encapsulation, inheritance, special methods, simple design patterns)***TP 07: File manipulation and data analysis***(Reading/writing files, word processing, introduction to Pandas and NumPy)***TP 08: Data preparation and processing for artificial intelligence***(Loading AI datasets, cleaning, transformation, feature selection)***Final project****Title:** Analysis and visualisation of a dataset + simple predictive model**Skills used:** Data reading, OOP, advanced structures, Pandas, Scikit-learn. (Oral presentation + written report).**Assessment method:**

exam 60%, CC =40%

Bibliography

- [1] E. Schultz and M. Bussonnier (2020): Python for the Humanities and Social Sciences. Introduction to data programming. Presses Universitaires de Rennes.
- [2] C. Paroissin, (2021): Practical data science with R: arranging, visualising, analysing and presenting data. Paris: Ellipses, DL 2021.
- [3] S. Balech and C. Benavent: NLP texte minig V4.0, (Paris Dauphine – 12/2019): link: https://www.researchgate.net/publication/337744581_NLP_text_mining_V40_-_une_introduction_-_doctoral_programme_course
- [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.. Learning to programme with 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). Learning to program with Python 3. Eyrolles, 6th edition. ISBN: 978-2212675214
- [9] Daniel, I. (2024). Learning to code in Python, J'ai lu
- [10] Nicolas, B. (2024). Python, from complete beginner to object-oriented programming: Lessons and corrected exercises, 3rd edition, Ellipses
- [11] Ludivine, C. (2024). Selenium Master your functional tests with Python, Eni

Online resources:

- Official Python documentation: docs.python.org
- Python exercises on Codecademy: [codecademy.com/learn/learn-python-3](https://www.codecademy.com/learn/learn-python-3)
- W3Schools Python Tutorial: [w3schools.com/python/](https://www.w3schools.com/python/)

Detailed programmes by subject for semester S2

Semester: 2
Teaching unit: UEF 1.2.1 Subject 1: Solar Radiation
VHS: 45 hours (Lectures: 1.5 hours, Tutorials: 1.5 hours)
Credits: 4
Coefficient: 2

Teaching objectives:

Reminders and applications of the first and second laws of thermodynamics in the field of power and cooling generation. Analysis of various engine and refrigeration cycles.

Thermal radiation is the energy emitted by matter at a finite temperature. Radiative energy emission can occur in solids, liquids and gases. The radiative field equation is carried by electromagnetic waves (or photons). In contrast to conductive or convective transfer, which requires a material medium, thermal radiation does not use one. In fact, transfer is more efficient in a vacuum. The emission of electromagnetic waves by the Sun is adequately modelled by a black body at 5,800 kelvins, and can therefore be described by Planck's law. This course *will* enable *students* to model the radiative exchanges that occur, for example, in agricultural greenhouses, in thermodynamic or photovoltaic solar collectors, in homes, and in many other technological fields that are too numerous to list exhaustively.

Recommended prior knowledge:

Knowledge of the main principles of technical thermodynamics: the first and second laws of thermodynamics and the principles of heat transfer.

Course content:

Chapter 1: General information on radiation (2 weeks)

- Heat transfer modes: conduction, convection and radiation
- Structure and origin of radiation
- Planck's law, conditions for radiation from a body, speed of propagation of electromagnetic waves and wavelength
- Principle of heating by classification of bodies subjected to radiation and law of conservation of energy

Chapter 2: Energy quantities (1 week)

- Classification, definition of energy quantities and Lambert's law

Chapter 3: Geometric measurement of beams (2 weeks)

- Beam width, solid angle, plane angle, etc.
- Lambert's Law for a hemispherical source
- Calculation of isotropic hemispherical flux
- Illuminance of the receiver as a function of the luminance of the emitter.

Chapter 4: Black bodies (3 weeks)

- Creation of a black body: the absorbing cavity
- Emission and absorption of black body radiation and Lambert's law

- Total and monochromatic energy emittance: Stephan's law, Wien's laws (1st and 2nd laws)
- Planck's law and Wien's laws (1st and 2nd laws)
- Integration of Planck's formula: Stephan's formula
- Fraction of total emittance contained in a spectral interval
- Application of radiation laws to solar energy
- Radiative flux between two black bodies in total influence

Chapter 5: The radiation of real bodies

(3 weeks)

- Emission factors of real bodies, different emissivities
- Emissivity and absorption of common bodies and Kirchhoff's law
- Example of calculating radiative exchanges in a black chamber

Chapter 6: Bodies under partial influence

(3 weeks)

- Flux exchange between two isothermal black surfaces separated by a transparent medium
- Shape factors
- Calculation of form factors for several configurations

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

1. Olivier PERROT. *Radiation course 2010/2011 I.U.T. of Saint-Omer Dunkirk* 2. G. BRUHAT, *Thermodynamics*, Masson Publishing
2. J.P. BARDON, *Surface Temperatures, Fundamental Concepts (R2730)*, Techniques de l'ingénieur Publishing
3. C. CHAUSSIN, C. HILLY and J. BARRALS *Heat and Thermodynamics*, Lavoisier Publishing.
4. Yunus A. Cengel and F. Ghajar, *Heat and Mass Transfer: Fundamentals and Applications*, 5th Edition, McGraw-Hill, 2014.
5. John R. Howell, M. Pinar Menguc and Robert Siegel, *Thermal Radiation Heat Transfer*, 5th Edition, CRC Press, 2011.

Semester: 2
Teaching unit: UEF 1.2.2
Subject 2: Hydroelectric and Wind Energy VHS: 45 hours (Lectures: 3 hours, Tutorials: 1.5 hours)
Credits: 4
Coefficient: 2

Teaching objectives:

Wind turbines (wind generators) are turbines that use wind power. Turbines (hydro generators) are turbines that use energy from dams and waterfalls. This teaching unit will enable students to acquire in-depth theoretical and practical knowledge of the components of wind turbines and hydraulic turbines used in electricity generation.

Recommended prior knowledge:

Knowledge of the main principles of technical thermodynamics: the first and second laws of thermodynamics and the principles of the main units of operation such as pumps, compressors, turbines, nozzles and diffusers.

Course content:

Chapter 1: Review of general hydraulics and turbines (2 weeks)

- Review of general hydraulics and flow characteristics
- Review of turbomachinery (hydraulic pumps and turbines)
- Turbine sizing and calculation (energy balance, examples, etc.)

Chapter 2: Effects of inertial forces - Balancing issues (3 weeks)

- Mass kinetics and inertia (centre of inertia, kinetic moments,
- inertia tensor of a non-deformable solid and Huygens' theorem
- Fundamental laws of dynamics - Force balances
- Balancing a rotor

Chapter 3: Principle of electrical energy production from hydraulic energy

(2 weeks)

- Implementation and environmental impact
- Study of a dam

Chapter 4: Hydroelectric power stations (2 weeks)

- Low-head hydroelectric power station
- High-head hydroelectric power station

Chapter 5: Theoretical concepts relating to wind turbines (4 weeks)

- Wind (Variations in wind speed over time and space
- Statistical study of wind
- Aerodynamics concepts
- Effects of air on the wing
- Parameters influencing C_z and C_x
- Aerodynamic calculation of a horizontal axis wind turbine (Betz theory, 3.3.2 Effects of rotation, Prandtl and Glauert corrections, etc.)
- Optimal blade dimensions for maximum power

Chapter 6: Wind Conversion Systems (WCS)**(2 weeks)**

- Various components, stand-alone wind power systems and grid-connected wind power systems (machines and converters, etc.)

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

- 1- Michel Lavabre, *Exercises and Problems in Energy Conversion: Volume 5, Renewable Energies (1): Wind Turbines, Energy Management and Storage*. Ed. Casteilla, 2010
- 2- Marc Rapin and Jean-Marc Noël, *Wind Energy Principles Case Studies*, Publisher: Dunod 2010.
- 3-R.V. Giles, *Fluid Mechanics and Hydraulics, Lectures and Problems, Schaum Series*, 1991.
- 4- Arne Kjølle, *Hydropower in Norway: Mechanical Equipment, a survey, Trondheim, December 2001*.
- 5- PACER, *Small Hydropower Plants, PACER Action Programme - Renewable Energy*, 1992. ISBN 3-905232-20-0
- 6- PACER, *Small Hydropower Plants: Hydraulic Turbines, PACER Renewable Energy Action Programme*, 1995. ISBN 3-905232-54-5
- 7- Mathieu Jenny:
- 8- Turbomachines - Hydraulic and Wind Energy 2015/2016. <http://energie.mines-nancy.univ-lorraine.fr/2A/turbo2a.pdf>
- 9- Caballina, O. 2011–2012 Theoretical concepts of wind turbines. ENSEM 3A course - Energy programme.
- 10- Gourieres, D. L. 2008 *Wind turbines: Theory, design and practical calculations*. Editions du Moulin Cadiou.
- 11- Geradin, M. & Rixen, D. 1996 *Vibration theory: application to structural dynamics*. Masson.
- 12- Hansen, M. O. 2008 *Aerodynamics of Wind Turbines – Second Edition*. Earthscan Edition.
- 13- Mahri, Z., Rouabah, M. & Zid, S. 2007 *Calculation of aerodynamic forces acting on the blades of a small wind turbine*. *Renewable Energy Review* 10 (2), 241–256.
- 14- Multon et al., *Electric wind turbines, Techniques de l'Ingénieur, Electrical Engineering Treatises*, 2004.
- 15- Rekioua, Djamilia, *Wind Power Electric Systems: Modelling, Simulation and Control 2014 Series: Green Energy and Technology*, EdSpringer, <http://www.springer.com/energy/renewable+and+green+energy/book/978-1-4471-6424-1>
- 16- Hau, *Wind-Turbines*, Springer, 2000.
- 17-J.F. Manwell, J.G. McGowan and A.L. Rogers " *Wind energy explained theory ,design and application University of Massachusetts, Amherst, USA*
- 18- Gary L. Johnson, " *Wind Energy Systems*," 10 October 2006
- 19- Hills, R. L. (1994) *Power from Wind*. Cambridge University Press, Cambridge, UK
- 20- Nelson, V. (1996) *Wind Energy and Wind Turbines*. Alternative Energy Institute, Canyon, TX.
- 21- Freris, L. L. (1990) *Wind Energy Conversion Systems*, Prentice Hall, London.
- 22- Jamil, M. (1994) *Wind Power Statistics and Evaluation of Wind Energy Density*. *Wind Engineering*
- 23- PACER, *Small Hydropower Plants: Regulation and Operational Safety, PACER Renewable Energy Action Programme*, 1995. ISBN 3-905232-56-1

- 24- *Introduction to Wind Energy Systems, Hermann-Josef Wagner and Jyotirmay Mathur, Publisher: Springer 2013.*
- 25- *Wind and Solar Power Systems, Mukund R. Patel, editor of Solar Energy Journal, published 2005.*

Semester: 2
Teaching unit: UEF 1.2.2
Subject 1: Solar thermal energy and applications VHS:
67.5 hours (Lectures: 3 hours, tutorials: 1.5 hours)
Credits: 6
Coefficient: 3

Teaching objectives:

Difference between low-temperature and high-temperature collectors in terms of use and design, detailed components of each type, calculation and dimensioning.

Recommended prior knowledge:

General information on solar radiation, radiative exchanges and different modes of heat transfer, thermodynamic laws, basic concepts of optics.

Course content:

Chapter 1: Review of Solar Radiation	(1 week)
Chapter 2: Thermal Conversion of Solar Energy	(3 weeks)
Chapter 3: Low-Temperature Collectors	(3 weeks)
Chapter 4: Solar Concentration	(4 weeks)
<ul style="list-style-type: none"> - Necessity of concentration, principle and components - Collectors - Working fluid, heat transfer fluid 	
Chapter 5: High-Temperature Solar Thermal Systems	
Temperature Concentration Systems	(4 weeks)
<ul style="list-style-type: none"> - The parabolic trough system - the Fresnel sector - the solar tower sector - the parabolic-sterling engine sector 	

Assessment method:

Examination: 60%, Continuous assessment: 40%

Bibliographical references:

- 1- Manuel Romero-Alvarez and Eduardo Zarza. *Concentrating Solar Thermal Power. Energy conversion*. D. Yogi Goswami, Frank Kreith.: Taylor & Francis Group, LLC. CRP Press 2008.
- 2- Keith Lovegrove, Andreas Luzzi. *Solar Thermal Power Systems, Encyclopedia of Physical Science and Technology, 3rd edition volume 15*.
- 3- T. Cabirol, A. Pelisson and D. Roux. *Solar water heating*. Edisud, Aix-en-Provence, 1976.

Semester: 2
Teaching unit: UEM 1.2
Subject 1: Setting up and sizing renewable energy projects VHS: 45 hours 300 (Lectures: 1 hour 30 minutes, Practical work: 1 hour 30 minutes)
Credits: 3
Coefficient: 2

Course objectives:

Acquire and master the scientific and technical knowledge necessary for the design, dimensioning and operation of energy systems and installations in general, and renewable energy systems in particular.

Become aware of the need to take environmental issues into account at all stages of project design and implementation.

Recommended prior knowledge:

Bachelor's degree programme in Fluid Mechanics. Fundamental Thermodynamics. Heat Transfer. Different types of Energy and Conversion Systems.

Course content:**Part I: Necessary scientific and technical knowledge design and dimensioning****(8 weeks)**

- Low Temperature Thermal Sensors
- PV System Technology.
- Wind Power System Technology.
- CSP technology.
- Fuel Cells,
- Heat Pumps and Heat Exchanger Technology.
- Waste-to-energy.
- Cogeneration and trigeneration.

Part II: Methodology and tools for setting up ER projects**(7 weeks)**

- Technical aspects (hydrology, civil engineering, turbomachinery, generators and electrical installations, regulation and operational safety).
- Methodology for setting up projects for DHW plants; PV; Wind power CSP.
- Economic aspects
- Software for sizing renewable energy installations: PVsys, etc.

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

- 1- *Project Management, Girard-ECONOMICA.*
- 2- *Business Engineer's Handbook, Fraysse-GARNIER ENTREPRISE.*
- 3- *Project Analysis Techniques, Vallet/DUNOD.*

Semester: 2
Teaching unit: UEM 1.2 Subject 2: Practical Conversion
VHS: 22.5 hours (practical work: 1.5 hours)
Credits: 2
Coefficient: 1

Teaching objectives:

Acquire knowledge about the origins and current use of solar and wind energy sources. Understand and test the operation of a solar and/or wind power installation by observing their behaviour and quantifying their performance. Experiment with PV electrical characterisation and the behaviour of a solar cell based on physical and dimensional parameters. This subject also aims to enable students to measure the characteristics of photovoltaic system components under different climatic conditions and in different practical situations.

Recommended prior knowledge:

Course content:

Part I: SOLAR PV energy (minimum of 2 practical sessions, depending on available resources) (8 weeks)

- **Reminders: POWER ELECTRONICS:** Definitions of different types of switching in static converters, Design and analysis methods for naturally switched static converters, Design and analysis methods for forced switched converters, Power quality of static converters, Numerical simulation of static converters
- **Practical work:**
 - **TP1:** Electrical characterisation of photovoltaic modules under normal climatic conditions (fully illuminated module) (simulation and/or experimental).
 - **TP2:** Electrical characterisation of photovoltaic modules under the effect of shading and understanding the role of bypass diodes (simulation and/or experimental).
 - **TP3:** Study of a photovoltaic system with and without storage (simulation and/or experimental).
 - **TP4:** Study of a photovoltaic pumping system (as the sun moves, and/or with storage. (Simulation and/or experimental).

Part II: WIND ENERGY (minimum of 2 practical sessions, depending on available resources) (7 weeks)

- **Reminders:** General Presentation of a Wind Power System, Concepts of Power and Quantification Methods.
- **Practical work:**
 - **Practical 1:** Wind modelling and simulation.
 - **Practical 2:** Modelling and simulation of a wind turbine.
 - **Practical 3:** Modelling and simulation of power converters used in wind power (inverter, rectifier).

- **TP4:** Modelling and simulation of a wind power conversion chain.

Recommendation: *organise a visit to a PV power plant, a wind turbine and/or a wind farm, etc.*

Assessment method:

Continuous assessment: 100%

Bibliographical references:

1. *A. Laugier, J. A. Roger, Les photopiles solaires, Techniques et documentation, 1981.*
2. *R. Patel Mukund, Wind and Solar Power Systems, Taylor & Francis, 2006.*
3. *W. Palz and P. Chartier. Energy from biomass in Europe. Applied Science Publishers, Ltd, London, 1980.*

Semester: 2
Teaching unit: UEM 1.2
Subject: Thermal metrology, control and regulation VHS: 37.5 hours (Lectures: 1 hour, Practical work: 1.5 hours)
Credits: 4
Coefficient: 2

Teaching objectives:

The objective of this unit is to enable learners to understand:

- the practical methods used in the various thermal characterisation devices and the overall methodology adopted for studying the different methods in the thermal field.
- the mastery of the process of any process process: mechanical, electrical, thermodynamic, chemical, etc.
- The different physical physical of transducers (sensors): photovoltaic, thermoelectric, piezoelectric, etc.
- Acquire basic knowledge of system regulation and control.
- The principles of linear regulated or servo systems (temperature regulation, air conditioning, production lines, etc.).
- The dynamic characteristics of a system, open-loop and closed-loop regulation.
- Basic control systems (PID, etc.) and adaptive learning systems.

Subject content:

Chapter 1: Temperature measurement

(1 week)

- Thermometer, platinum resistance, IR detector and IR camera, etc.
- Choice of measurement method and sensitivity study.
- Method of estimation, evaluation of parameters and accuracy.

Chapter 2: Hot plate and hot wire methods

(2 weeks)

- Principles and modelling, parameter estimation and implementation.
- Measurement practice and limitations.
- Principles, modelling and estimation of thermal diffusivity.
- Practical implementation of measurement and limitations of the method.

Chapter 3: Other methods

(2 weeks)

- Semi-infinite and finite hot plate.
- Finite hot plate method with constant and finite asymmetrical auger with isolated auger face.
- Hot tape, hot disc and mini hot plate methods.

Chapter 4: Control system modelling

(2 weeks)

- Transfer function.
- Index response.
- Response to a step input.
- Effects of zeros on the system

Chapter 5: Performance, stability and correction of a control system**(4 weeks)**

- Temporal performance of the system.
- Steady state (regulation).
- System frequency performance.
- Absolute stability, relative stability.
- Proportional, integral and derivative actions.

Chapter 6. Analogue-to-digital signal processing**(4 weeks)**

- Fourier transform of a discrete signal.
- Discrete Fourier transform.
- Concept of fast Fourier transform.
- Convolution.
- Concept of filtering.
- Concept of modulation.

Assessment method:

Continuous assessment: 40%; Examination: 60%.

Bibliographical references:

1. *Dominique Placko, "Measurement and Instrumentation: Volume 1. From Sensor Physics to Electrical Signals," Publisher: Hermès – Lavoisier, October 1970.*
2. *Maitine Bergouniou, "Mathematics for Signal Processing - Lectures and Corrected Exercises," SCIENCES SUP – Dunod, 2010.*
3. *M. Benidir, "Signal Theory and Processing: Volume 1 - Representation of Signals and Systems," Collection: Sciences Sup, Dunod, 2002.*
4. *Physical measurements and instrumentation: Statistical and spectral analysis of measurements, sensors," Barchiesi, Dominique, Paris, Ellipse, 2003.*
5. *Sensors in Industrial Instrumentation, Asch, Georges, Paris, Dunod, 1999.*
6. *Physical properties of certain bodies.2: physical properties of air and water*
7. *Theory and practice of thermal metrology – Yves Jannot – 2011*
8. *Integral transforms: Laplace, Fourier, Hankel: inverse Laplace transform.*

Semester: 2

Teaching unit: UET 1.2

Subject: Compliance with standards and rules of ethics and integrity. VHS: 22.5 hours (Lectures: 1.5 hours)

Credits: 1

Coefficient: 1

Teaching objectives:

To develop students' awareness of ethical principles and rules governing university life and the world of work. To raise awareness of the importance of respecting and valuing intellectual property. To explain the risks of moral ills such as corruption and how to combat them, and to alert students to the ethical issues raised by new technologies and sustainable development.

Recommended prior knowledge:

Ethics and professional conduct

Course content:

A. Respect for rules of ethics and integrity

1. Reminder of the MESRS Ethics and Professional Conduct Charter: Integrity and honesty. Academic freedom. Mutual respect. Commitment to scientific truth, objectivity and critical thinking. Fairness. Rights and obligations of students, teachers, administrative and technical staff.

2. Integrity and responsible research

- Respect for ethical principles in teaching and research
- Responsibilities in teamwork: Professional equality of treatment. Conduct against discrimination. The pursuit of the public interest. Inappropriate conduct in the context of collective work
- Adopting responsible conduct and combating misconduct: Adopting responsible conduct in research. Scientific fraud. Conduct against fraud. Plagiarism (definition of plagiarism, different forms of plagiarism, procedures to avoid unintentional plagiarism, detection of plagiarism, sanctions against plagiarists, etc.). Falsification and fabrication of data.

3. Ethics and professional conduct in the workplace:

Legal confidentiality in business. Loyalty to the company. Responsibility within the company, conflicts of interest. Integrity (corruption in the workplace, its forms, consequences, ways of combating it and sanctions against corruption)

B- Intellectual property

I- Fundamentals of intellectual property

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

II- Copyright

1. Copyright in the digital environment

Introduction. Copyright in databases, copyright in software. The specific case of free software.

2. Copyright on the internet and in e-commerce

Domain name law. Intellectual property on the internet. E-commerce website law. Intellectual property and social media.

3. Patents

Definition. Rights in a patent. Usefulness of a patent. Patentability. Patent applications in Algeria and worldwide.

III- Protection and promotion of intellectual property

How to protect intellectual property. Infringement of rights and legal tools. Exploitation of intellectual property. Protection of intellectual property in Algeria.

C. Ethics, sustainable development and new technologies

Link between ethics and sustainable development, energy saving, bioethics and new technologies (artificial intelligence, scientific progress, Humanoids, robots, drones,

Assessment method:

Examination: 100%

Bibliographical references:

1. Charter of Academic Ethics and Professional Conduct, <https://www.mesrs.dz/documents/12221/26200/Charte+français+df.pdf/50d6de61-aabd-4829-84b3-8302b790bdce>
2. Decree No. 933 of 28 July 2016 establishing rules on the prevention and combating of plagiarism
3. E. Prairat, De la déontologie enseignante (On teaching ethics). Paris, PUF, 2009.
4. Racine L., Legault G. A., Bégin, L., Ethics and Engineering, Montreal, McGraw Hill, 1991.
5. Siroux, D., Ethics: Dictionary of Ethics and Moral Philosophy, Paris, Quadrige, 2004, pp. 474-477.
6. Medina Y., Ethics: What Will Change in the Workplace, Éditions d'Organisation, 2003.
7. Didier Ch., Penser l'éthique des ingénieurs (Thinking about engineering ethics), Presses Universitaires de France, 2008.
8. Gavarini L. and Ottavi D., Editorial. Professional Ethics in Training and Research, Research and Training, 52 | 2006, 5-11.
9. Caré C., Morals, Ethics, Professional Conduct. Administration and Education, 2nd quarter 2002, no. 94.
10. Jacquet-Francillon, François. Concept: professional ethics. Letélémaque, May 2000, no. 17
11. Carr, D. Professionalism and Ethics in Teaching. New York, NY Routledge. 2000.
12. Galloux, J.C., Industrial Property Law. Dalloz 2003.
13. Wagret F. and J-M., Patents, trademarks and industrial property. PUF 2001
14. Dekermadec, Y., Innovating through patents: a revolution with the internet. Insep 1999
15. AEUTBM. Engineers at the heart of innovation. Belfort-Montbéliard University of Technology
16. <http://www.app.asso.fr/>
17. <http://ressources.univ-rennes2.fr/propriete-intellectuelle/cours-2-54.html>
18. Fanny Rinck and Léda Mansour "Literacy in the digital age: copy-paste among students" University of Grenoble 3 and University of Paris Ouest Nanterre La Défense Nanterre, France
19. The ABCs of Copyright, United Nations Educational, Scientific and Cultural Organisation (UNESCO)
20. Alain Bensoussan White Paper – Open Science in a Digital Republic Directorate of Scientific and Technical Information CNRS
21. Copyright in the cultural industries. - Cheltenham: E. Elgar, 2002. - XXII-263 p.
22. Similarity detection software: a solution to electronic plagiarism? Report by the Working Group on Electronic Plagiarism presented to the CREPUQ Subcommittee on Pedagogy and ICT
23. Emanuela Chiriac, Monique Filiatrault and André Régimbald. "Student guide: intellectual integrity, plagiarism, cheating and fraud... how to avoid them and, above all, how to cite your sources correctly" 2014

24. Publication by the University of Montreal. "Plagiarism Prevention Strategies," Integrity, Fraud and Plagiarism, 2010
25. Pierrick Malissard "Intellectual property: origin and evolution" 2010.
26. The World Intellectual Property Organisation website www.wipo.int.

Semester: S2

Teaching unit: 1.2.1

Subject: Elements of applied artificial intelligence VHS:

45 hours (1.5 hours of lectures, 1.5 hours of practical work)

Credits: 2

Coefficient: 2

Targeted skills:

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

Objectives:

- Mastery of AI algorithms
- Introduction to the fundamental concepts, tools and applications of modern artificial intelligence, with an emphasis on practical application using Python and its libraries.
- Deepening your knowledge of Python,
- Understanding AI approaches to problem solving,

Prerequisites:

Advanced Python programming

Required equipment:

- A computer with Python installed,
- Python libraries: NumPy, Pandas, Scikit-learn, Matplotlib, os.listdir, os.path.exists, os.mkdir, os.rmdir, Matplotlib, Seaborn, Plitly, Request, Beautiful Soup, Tkinter, PyQt, etc.
- Tensorflow, PyTorch, etc.

Course content:

Chapter 1: Introduction to artificial intelligence (AI)

(1 week)

1. Definitions and fields of application of AI.
2. Historical evolution of AI.
3. Introduction to the main areas:
 - 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, optimisation.
 - Implementation with **Scikit-learn**.
4. **Exercises:**
 - Matrix manipulation with the NumPy library (Python)
 - Exercise on linear regression (using a Python library such as Scikit-learn, for example)
 - Explaining the Matplotlib library (Python)
 - ...

Chapter 3: Machine Learning

(3 weeks)

1. Key concepts: Data, models, features, labels, generalisation.
2. Phases of a learning pipeline: training, validation, testing.
3. Types of learning:
 - Supervised

- Unsupervised
- Reinforcement (*overview*)

4. Exercises:

- Reinforce concepts covered in class
-

Chapter 4: Supervised classification

(3 weeks)

1. Principle of training a simple classification model:
2. Models and algorithms:
 - SVM (Support Vector Machine)
 - Decision trees
3. Performance evaluation:
 - Confusion matrix, precision, recall, F1 score.
5. Exercises:
 - Explain how to use Scikit-learn?
 - Comparison of several models on a dataset
 -

Chapter 5: Unsupervised learning

1. The concept of clustering.
2. Algorithms:
 - **K-means**
 - DBSCAN (Density-Based Spatial Clustering of Applications with Noise)
3. 2D visualisation and interpretation of results.
4. Exercises:
 - Explain how to use a clustering algorithm on a dataset
 - Explain how to visualise clusters.
 - ...

Chapter 6: Neural networks

1. Architecture of a neural network:
 - Perception,
 - Layers and hidden layers, weights, bias.
 - Activation function: ReLU, Sigmoid, Softmax, etc.
 - Application exercises
2. Introduction to **Deep Learning**:
 - Concept of deep layers.
 - Introduction to convolutional neural networks (CNN)
3. Exercises:
 - Explaining Tensorflow and PyTorch
 - Analyse a text dataset and predict sentiments
 - ...

Chapter 7: Mini project (supervised personal work outside of class):

Create a complete classification or clustering model, including pre-processing, training and visualisation; choose and complete a project from start to finish from among the following (to be distributed at the beginning of the semester):

- Handwritten character recognition
- Prediction of natural disasters
- Develop a chatbot capable of answering frequently asked questions about a company in a natural way.
- Develop a system capable of distinguishing between normal machine sounds and those indicating a fault (defective bearing, excessive vibration, etc.).
- Develop a system (mini AI) capable of analysing the sentiments expressed in social media posts about a product, brand or event.

○ ...

Practical work:

TP 01: Initialisation

TP 02:

- Implement a simple regression with Scikit-learn Visualisation with Matplotlib (for example)
- Visualising results with Matplotlib
- ...

TP 03:

- Machine learning pipeline and data separation
- Further exploration of concepts covered in class

Practical assignment 04:

- Using Scikit-learn to train a simple classification model
-

Practical 05:

- Implementing a clustering algorithm on a dataset
- Visualising clusters: Unsupervised clustering (K-means, DBSCAN).
-

TP 06:

- Build a simple neural network with TensorFlow, PyTorch, or Keras
- Build a simple CNN to classify images (example: MNIST dataset)
- ...

Assessment method:

60% examination, 40% CC

Bibliography:

- Ganascia, J. Gabriel (2024): AI Explained to Humans. Paris, France: Edition le Seuil.
- Anglais, Lise, Dilhac, Antione, Dratwa, Jim et al. (2023): Ethics at the heart of AI. Quebec Obvia.
- J. Robert (2024): Natural Language Processing (NLP): definition and principles – Data science.
Link: <https://datascientest.com/introduction-au-nlp-natural-language-processing>
- What is natural language processing? Link: <https://aws.amazon.com/fr/what-is/nlp/>
- M.Journe: Elements of Discrete Mathematics – Ellipses
- F.Challet: Deep learning with Python – Eyrolles
- H. Bersini (2024): Artificial Intelligence in Practice with Python – Eyrolles
- B. Prieur (2024): Automatic Natural Language Processing with Python – Eyrolles
- V. Mathivet (2024): Implementation in Python with Scikit-learn – Eyrolles
- G. Dubertret (2023): Introduction to Cryptography with Python – Eyrolles
- S.Chazallet (2023): Python 3 – The Fundamentals of the Language – Eyrolles
- H. Belhadef, I. Djemal: TALN Method – Course from the University of Msila – Algeria

Detailed programmes by subject for semester S3

Semester: 3
Teaching unit: UEF2.1.1
Subject 2: Energy efficiency and building thermodynamics VHS: 45
hours (Lectures: 1.5 hours, Tutorials: 1.5 hours)
Credits: 4
Coefficient: 2

Course objectives:

Students will learn to assess the energy consumption of a new or existing building and propose energy-saving measures. They will learn to determine the energy requirements of a dwelling, master the various solar systems related to housing, size a heating system for a dwelling, and master bioclimatic techniques.

This course also teaches students the basic principles of energy efficiency. It provides them with information on many terms used in the energy sector, on different energy sources, on how electricity is produced and how it is used in industry. One of the main objectives of this course is to show how we can use energy more efficiently, make it cleaner, produce it from renewable sources, and manage it better, particularly to reduce the waste it generates.

Recommended prior knowledge:

Heat transfer course S thermodynamics, fluid mechanics, concepts of regulations and standards on conventional and renewable energies.

Course content:

- | | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Chapter 1: Energy sources | (2 weeks) |
| <ul style="list-style-type: none"> - Tariffs used - Billing analysis. - Reminder of electromechanical systems in buildings: HVAC systems (heating, ventilation and air conditioning) | |
| Chapter 2: Role of a centralised building control system | (1 week) |
| Chapter 3: Energy audit of a building | (2 weeks) |
| <ul style="list-style-type: none"> - Assessment of annual energy consumption in a building - Detailed methods for calculating energy consumption | |
| Chapter 4: Energy saving in chillers and boilers | (1 week) |
| Chapter 5: HVAC systems and heat recovery | (2 weeks) |
| Chapter 6: Building energy modelling and simulation | (3 weeks) |
| <ul style="list-style-type: none"> - Energy efficiency of thermal processes using steam as a heat transfer medium. Measurement techniques used in high-pressure and high-temperature steam systems. - Methods for detecting steam leaks. | |
| Chapter 7: Building thermodynamics | (4 weeks) |

- Classification of different solar heating systems.
- Heating requirements of a house
- Direct gain heating.
- Storage wall system.
- Variable insulation system.
- Thermosiphon.
- Active systems.
- Systems with auxiliary heating.
- Bioclimatic houses.
- Solar ponds.

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

- 1- Rob Aldrich and Jon Parello; *IP-Enabled energy management: a proven strategy for administering energy as a service*, Wiley Publishing Inc, USA 2010; ISBN: 978-0-470-60725-1.
 - 2- Algerian laws and decrees on energy
 - 3- Smil Vaclay, *Energy, Myths and Realities*, AEI Press, 2010
 - 4- E. Félice, P. Révilla, "Quality of electrical networks and energy efficiency", Dunod, 2009
 - 5- McKane, et al, 2007, UNIDO publication, *Policies for Promoting Industrial Energy Efficiency in Developing Countries and Transitional Economies v. 08-52434- April 2008*.
www.iso.org/iso/fr/focus_1105_sr_pinero.pdf (retrieved on 27 May 2016).
 - 6- ISO/TC 242 Energy management, http://www.iso.org/iso/fr/iso_technical_committee?commid=558632 (retrieved on 27 May 2016).
 - 7- Douglas F. Barnes; Kerry KruLilla and William F. Hyde; *The Urban Household Energy Transition: Social and Environmental Impacts; An AFF Press Book*, published by Resources of the Future, USA 2004, ISBN: 1-933115-07-6.
 - 8- *Thermodynamics [An Engineering Approach]* by Yunus A. Cengel and Michael A. Boles, 5th edition, 2006.
 - 9- *Thermodynamics-and-heat-powered-cycles--a-cognitive-engineering-approach* by: ChihWu . Nova Science Publishers; 2007; ISBN-10 / ASIN: 1600210341.
 - 10- *Fundamentals of Engineering Thermodynamics: By Michael J. Moran, Howard N. Shapiro*. Wiley; 2007; ISBN-10 / ASIN: 0471787353.
 - 11- *Introduction to Thermal Systems Engineering: Thermodynamics, Fluid Mechanics, and Heat Transfer* by Michael J. Moran / Howard N. Shapiro / Bruce R. Munson / David P. DeWitt; Wiley; ISBN: 0471204900.
- 1-

Semester: 3
Teaching unit: UEF 2.1.1
Subject 1: Working Fluids, Materials and Storage Devices VHS: 45
hours (Lectures: 1.5 hours, Tutorials: 1.5 hours)
Credits: 6
Coefficient: 3

Teaching objectives:

Acquire general knowledge about different types of energy: reserves, production, consumption, use, renewable or non-renewable, pollution, future.

The knowledge to be acquired depends on the course, but includes techniques and processes related to energy storage and new concepts in energy production.

When choosing a working fluid (heat transfer fluid) used to transfer heat between two points for an application, it is generally desirable for it to deliver high energy performance, be suited to the operating conditions of the cycle, be economically viable and comply with current regulations. The criteria for selecting fluids for refrigeration cycles may, of course, differ from those for Rankine cycles.

The issues also differ depending on whether you are designing a new installation or changing the fluid in an existing one. In the latter case, the thermodynamic characteristics of the replacement fluid must be similar to those of the original, whereas in the former case, the change can sometimes improve the performance of the installation. The critical temperature and pressure values are very important. These data determine the upper pressure limit of the cycle. Near the critical pressure, a very small change in temperature can cause a significant change in pressure, which can influence the behaviour of the system.

Recommended prior knowledge:

Bachelor's degree programme in Fluid Mechanics. Fundamental Thermodynamics. Heat Transfer. Environmental Characteristics. Different Types of Energy. Basic Chemistry.

Course content:

Chapter 1: Thermoelectric Materials (3 weeks)

- Theory of thermoelectricity,
- thermoelectric materials
- nanometric materials: new trends and manufacturing techniques

Chapter 2: Bioenergy materials and biomass (3 weeks)

- Characterisation methods Bioenergy and biomass
- Energy conversion and transduction systems in living organisms – Biomass, biofuel and biobatteries
- Electrochemical energy storage

Chapter 3: Conventional energy storage technologies (5 weeks)

- Lead-acid batteries, alkaline batteries Lead-acid batteries (Electrode manufacturing processes.
- Battery assembly. Open and gas recombination batteries. Compressed lead) Ni hydride technology Ni-Cd and Ni-MH batteries (Alkaline couples. Ni-Cd.

- Ni-MH: technologies and materials. Self-discharge and memory effect) Li metal and Li ion technologies Lithium batteries (Solid-state electrochemistry.
- Lithium-ion and Li-metal accumulators. Micro-accumulators) Other accumulators (Ni-Zn alkaline batteries, metal-air generators, high-temperature accumulators, etc.) Supercapacitors (mesoporous and microporous graphite, capacitive storage in the electrochemical double layer, ionic liquids)
 - Assembly of a lithium metal battery in a glove box and testing by electrochemical impedance and discharge/charge curve UE4.3. Energy savings Insulation, lighting technologies, combustion, etc.

Chapter 4: Working fluid in RE

(4 weeks)

- Fluid selection: thermodynamic issues and selection criteria,
- Simulation of solar energy systems
- Qualitative analysis of cycles; Comparisons with Carnot.
- Exergy analyses
- Environmental quality indicators

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

- 01- *Adrien Lomonaco, "Thermal Energy Storage Using Phase Change Materials Suitable for Thermodynamic Solar Power Plants," members of the jury, University of Pau and Pays de l'Adour (doctoral thesis, PDF)*
- 02- *Practical Handbook of Photovoltaics: Fundamentals and Applications, Luis Castaner and Tom Markvart, Publisher: Elsevier Science Ltd, 2003.*
- 03- *LAGHZAOU, (Amine) PEERHOSSAINI (Donia) "HEAT STORAGE: SOLAR ENERGY AND OTHER APPLICATIONS (course pdf) ECOLE DES MINES DE DOUAI 2010.*
- 04- *X. Py, N. Calvet, R. Olivès, P. Echegut, C. Bessada, F. Jay; "Low cost recycled material for thermal storage applied to solar power plants", SOLARPACES, Concentrating solar power and chemical energy systems, 15-18 September 2009, Berlin, Germany.*
- 05- *X. Py, N. Calvet, R. Olivès, P. Echegut, C. Bessada, F. Jay; "Low cost material for sensible heat based thermal storage to be used in thermodynamic solar power plants". ASME, 3rd International conference on energy sustainability, 19–23 July 2009, San Francisco, California, USA.*
- 06- *Ashby Jones: Materials: I- Properties and Applications Dunod (1998).*
- 07- *Ashby Jones: Materials: II- Microstructure and implementation, Dunod (1991).*
- 08- *X. Py, N. Calvet, R. Olivès, P. Echegut, C. Bessada, F. Jay; "Thermal storage for solar power plants based on low-cost recycled material". EFFSTOCK, the 11th International Conference on Thermal Energy Storage, 14-17 June 2009, Stockholm, Sweden*
- 09- *N. Calvet, R. Olivès, J.P. Bédécarrats, X. Py, J.P. Dumas, F. Jay; "Latent heat storage enhancement by thermal conductivity intensification". EFFSTOCK, the 11th International Conference on Thermal Energy Storage, 14-17 June 2009, Stockholm, Sweden.*
- 10- *Rekioua, D., Matagne, E., Chapter 1: Photovoltaic Applications Overview in Optimisation of Photovoltaic Power Systems: Modelling, Simulation and Control 2012 Series: Green Energy and Technology. Ed Springer <http://www.springer.com/gp/book/9781447123484>*
- 11- *C. Kittel: Solid State Physics, Dunod Université Bordas (1983).*
- 12- *W.KURZ, J.P. MERCIER and G. ZAMBELLI: Introduction to Materials Science, Presses Polytechniques Romandes, (1987)*
- 13-

Semester: 3
Teaching unit: UEF 2.1.2
Subject 2: Solar photovoltaics and applications VHS:
45 hours (Lectures: 1.5 hours, Tutorials: 1.5 hours)
Credits: 4
Coefficient: 2

Course objectives:

Acquisition of the scientific and technical foundations necessary for professional mastery of **photovoltaic solar** energy applications.

Acquire the knowledge necessary to work in companies involved in PV project development, PV power plant operation, and PV energy production system design.

Recommended prior knowledge:

Semiconductor materials – Radiation and conversion – Basic electronics.

Course content:

Chapter 1: Photovoltaic electricity and photovoltaic converters (3 weeks) (Photovoltaic effect, fundamentals of photovoltaic conversion, properties of semiconductors, physics of solar cells, etc. Equivalent circuit and parameters of a solar cell, current-voltage diagram (I-V), influence of climatic parameters, influence of electrical parameters, etc.)

Chapter 2: Photovoltaic systems (3 weeks)

(Classic architecture of different photovoltaic conversion chains, Autonomous systems

Direct connection between the photovoltaic panel and the load, grid-connected conversion systems. And techniques for optimising PV systems (*sun tracking, concentration cells, etc.*)

Chapter 3 Static converters and charge controllers (2 weeks) (Definition and types of converters (DC/DC: choppers and DC/AC: inverters and grid-connected inverters, etc.)

Chapter 4: Charge controllers and storage systems (2 weeks)

(Storage types, lead-acid batteries and charge and discharge characteristics)

Chapter 5: Sizing and managing a PV project (5 weeks)

(Building lighting, street lighting, pumping, solar tracking, etc.);

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

01- Anne Labouret and Michel Vill, *Photovoltaic Solar Energy*, oz, Publisher: Duno, 2005.

02- Rekioua, D., Matagne, E., *Optimisation of photovoltaic power systems: Modelling, Simulation and Control 2012 Series: Green Energy and Technology*. Springer Publishing <http://www.springer.com/gp/book/9781447123484>

- 03- T. Markvart, L. Castafier, "Practical Handbook of Photovoltaics: Fundamentals and Applications". Ed. Elsevier.
- 04- Practical Handbook of Photovoltaics: Fundamentals and Applications, Luis Castaner and Tom Markvart, Edition: Elsevier Science Ltd, 2003.
- 05- M. Tissot, "Le guide de l'énergie solaire et photovoltaïque" (The Guide to Solar and Photovoltaic Energy), Eyrolles, 2008.
- 06- L. Protin, S. Astier, "Photovoltaic Converters", Engineering Technique, Electrical Engineering Treatise, 1997.
- 07- Photovoltaic Converters, Alain Ricaud, Nov 2007
- 08- Alain, Bardet Luc. "Photovoltaic Solar Panels—Ecological Homes, Sustainable Construction and Housing—Luc A. Bardet." (2016).
- 09- Green, Martin A. "Solar cells: operating principles, technology, and system applications." (1982).
- 10- Bube, Richard. *Fundamentals of solar cells: photovoltaic solar energy conversion*. Elsevier, 2012.
- 11- Haberlin, Heinrich. *Photovoltaics: system design and practice*. Wiley, 2012.

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Semester: 3
Teaching unit: UEF 2.1.2
Subject 2: Fuel cells and hydrogen production VHS: 45 hours
(Lectures: 1 hour 30 minutes, Tutorials: 1 hour 30 minutes)
Credits: 4
Coefficient: 2

Course objectives:

Understand how fuel cells work, identify and characterise their components, measure their nominal characteristics and actual energy efficiency, and identify their main applications. How can electrical energy (wind, solar, hydrogen) be produced in an isolated location? How can basic knowledge of electrochemistry (oxidation-reduction reactions) be used to convert energy? How can the calorific value of hydrogen and continuous electrical power be calculated? How can the conversion facility be made safe?

Recommended prior knowledge:

Concepts of voltage, current, electrical power, efficiency. Knowledge of energy quantities. Dangers of electrical current and hydrogen. Basic knowledge of electrochemistry (oxidation-reduction reactions) for energy conversion.

Course content:

- | | |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Chapter 1: Introduction to fuel cells | (2 weeks) |
| <ul style="list-style-type: none"> - History - Operating principle | |
| Chapter 2: Different types of fuel cells | (2 weeks) |
| <ul style="list-style-type: none"> - Different types of fuel cells and how they work - Low-temperature fuel cells - High-temperature fuel cells | |
| Chapter 3: Fuel Cell Applications | (2 weeks) |
| <ul style="list-style-type: none"> - Advantages of fuel cells - Disadvantages of fuel cells - Fuel cells for electric vehicles | |
| Chapter 4: Hydrogen Production | (4 weeks) |
| <ul style="list-style-type: none"> - Steam forming - Water electrolysis - Production from renewable energies <ul style="list-style-type: none"> - <i>Solar thermal (high temperature)</i> - <i>Photovoltaic (photoelectrolysis)</i> - <i>Production from biomass</i> | |
| Chapter 5: Fuel cell modelling | (3 weeks) |
| <ul style="list-style-type: none"> - Standard reaction quantities - Electromotive force - Voltage - Power | |

- Reagent flow rate
- Efficiency
- Sizing a fuel cell installation

Chapter 6: Risks associated with hydrogen production and storage (2 weeks)

- Risk: ignition or explosion
- Mechanical risk: high temperature and high pressure
- Toxic and corrosive properties
- Hydrogen transport and storage techniques

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

a- Books

- 01- Pierre Mayé: *Electrochemical Generators: Batteries, Accumulators and Fuel Cells*, Dunod Publishing, 2010
- 02- Yves Bréelle, Odile Bloch, Paul D&gobert, Michel Prigent: *Principles, technology and applications of fuel cells*. Editions Tchnip 1972
- 03- *Hydrogen production techniques and associated risks: study report*, INERIS 2008
- 04- E. Marty, *The hydrogen sector: Hydrogen, the energy vector of the future?*, UCL (2002)
- 05- SAHLI M. "Study of hydrogen production and fuel cells" - Thesepdf - U Constantine Algeria 2010
- 06- Gérald POURCELLY "Hydrogen storage, fuel cells" European Institute for Membranes, CNRS Institute of Chemistry Director of the GDR Fuel Cells and Systems (PACS) 2013
- 07- D. R. Cohn, L. Bromberg, A. Rabinovich, N. Alexeev, *Hydrogen manufacturing using low current, non-thermal plasma boosted fuel converters*, PSFC/RR-01-1 (2001)

b- Online sources

- 01- "What place for hydrogen in the energy system?" Reflection Group on Energy and the Environment in the 21st Century
[2015http://www.sfen.org/sites/default/files/public/atoms/files/quelle_place_pour_l27hydrogene.pdf](http://www.sfen.org/sites/default/files/public/atoms/files/quelle_place_pour_l27hydrogene.pdf)
- 02- FUEL CELLS: TECHNOLOGIES AND APPLICATIONS Prof. Affolter Jean-François
University of Applied Sciences of Western Switzerland Institute of Electrical Energy Systems CH-1401 Yverdon
- 03- Julien Rodriguez. *Hydrogen production by photocatalysis and electrochemical conversion in a fuel cell*. Other. University of Grenoble Alpes, 2013. French. HAL Id: tel-00978688 (2014).<https://tel.archives-ouvertes.fr/tel-00978688>
- 04- Stevens, Philippe, et al. "Fuel cells." *Engineering techniques. Electrical engineering 5*.D3340 (2000): D3340-1.
- 05- Roger CadierguesMémoCad nB42.a " FUEL
http://media.xpair.com/auxidev/nB42a_PilesComb.pdf
- 06- ENERIS: *STUDY REPORT 10/06/2008 No. DRA-08-95313-07833B Hydrogen production techniques and associated risks*,
http://www.ineris.fr/centredoc/Techniques_prod_H2_web.pdf
- 07- French Association for Hydrogen and Fuel Cells "Hydrogen in France" 2015

- 08- Jean Marie Tarascon: *Hydrogen industry: from production to storage* Collège de France 2011 (PDF presentation: https://www.college-de-france.fr/media/jean-marie-tarascon/UPL58650_hydrogenecollege.pdf).
- 09- *Everything you wanted to know about fuel cells* https://www.college-de-france.fr/media/jean-marie-tarascon/UPL58650_hydrogenecollege.pdf
- 10- M. Belatel, F.Z. Aissous and F. Ferhat: "Contribution to the study of a PEMFC fuel cell used for green electricity production" http://www.cder.dz/vlib/revue/pdf/v015_n1_texte_2.pdf
- 11- Source: http://www-dsv.cea.fr/themes-de-recherche/biotechnologies/bio_hydrogen-new-energy-technologies/production-of-hydrogen-by-photosynthetic-organisms.

Semester: 3
Teaching unit: UEF 2.1.2
Subject 2: Maintenance of ER systems
VHS: 22.5 hours (Lectures: 1.5 hours)
Credits: 2
Coefficient: 1

Teaching objectives:

For a project owner, the guarantee of having made a sound investment, both technically and financially, is paramount. Ensuring high-performance systems is one thing, ensuring sustainable performance is another. Precise knowledge of the operating conditions of the solar installation is essential for it to achieve optimal energy efficiency in line with what was sold. This requires successful commissioning, which is ensured through intelligent maintenance and operation, among other things.

Recommended prior knowledge:

Basic knowledge of renewable energy installations, in particular solar water heaters, solar photovoltaic lighting and simple wind turbines, etc.

Course content:

Chapter 1: Principles and Operation of Systems	(2 weeks)
Chapter 2: Installations, connection diagrams and general instructions and general instructions	(5 weeks)
Chapter 3: Sensor cleaning, battery maintenance (3 weeks)	
Chapter 4: Maintenance levels, inspection and troubleshooting	(3 weeks)
Chapter 5: Installation, inspection and maintenance sheets	(2 weeks)

Assessment method:

Examination: 100%.

Bibliographical references:

1. *Jean-Claude Francastel, La fonction maintenance : De l'expression à la satisfaction du besoin (The maintenance function: From expression to satisfaction of needs), Publisher AFNOR, 2007.*
2. *Pascal Denis, Pierre Boye, André Bianciotto, Guide to Industrial Maintenance, DELAGRAVE Publishers, 2008.*
3. *Dunod, Pratique de la maintenance industrielle en 5 volumes - Méthodes, Outils, Applications (Industrial maintenance practice in 5 volumes - Methods, Tools, Applications): CD-ROM, EdsDunod, 2006.*

Semester: 3
Teaching unit: UEM 2.1
Subject 1: Simulation and dimensioning software for ER installations VHS: 22.5 hours (1.5 hours of practical work)
Credits: 2
Coefficient: 1

Course objectives:

By the end of this course, students will be able to use specialised codes as simulation and assessment tools to model and analyse renewable energy systems, establish energy databases, optimise performance and evaluate economic aspects.

Recommended prior knowledge:

Identification of simulation software: PV SYST; METEONORM; TRN SYS; SAM; etc.

Course content:

- Presentation of simulation and expertise codes in renewable energies **(2 weeks)**
- Modelling of renewable energy installations **(3 weeks)**
- Implementation of tools for sizing and
Simulation of energy systems **(3 weeks)**
- Evaluation of resources, conversion processes,
system performance **(3 weeks)**
 - Optimisation of energy system components **(2 weeks)**
- Technical and economic assessment of energy systems **(2 weeks)**

Recommendation:**Assessment method:**

Continuous assessment: 100%

Bibliographical references:

- 01- *Software guides for SAM, TRNSYS, RETScreen and Polysun.*
- 02- *Fay, J. A., and Golomb, D. S., "Energy and Environment," Oxford University Press, 2002.*
- 03- *Kutz, M., "Environmentally Conscious Alternative Energy Production," John Wiley & Sons, 2007.*
- 04- *Hodge, B. K., "Alternative Energy Systems and Applications," John Wiley & Sons, 2010.*

01-

Semester: 3
Teaching unit: UEM2.1
Subject 2: Solar cooling and air conditioning
VHS: 15 hours (1 hour of practical work)
Credits: 1
Coefficient: 1

Teaching objectives:

The term "solar air conditioning" refers to all methods of air conditioning that use the sun's heat as their primary energy source. This method of air conditioning, which can replace the use of fossil fuels, has the main advantage of being able to provide the most cooling when it is hottest, which generally corresponds to the periods when the sun is most available. There are three types of solar air conditioning: absorption machines, adsorption machines and desiccation machines.

Recommended prior knowledge:

Bachelor's degree programme in Fluid Mechanics. Fundamental Thermodynamics. Heat Transfer. Environmental Characteristics. Different Types of Energy. Basic Chemistry.

Course content:

Chapter 1: General principles of refrigeration, reminders (1 week)

Chapter 2: Solar refrigeration: general principles, solar collectors (2 weeks)

Chapter 3: Cycles and sorption machines (2 weeks)

- two liquid-vapour equilibria
- liquid absorption cycle
- performance and building integration: calculation, dependencies

Chapter 4: Endothermic phenomena (2 weeks)

- main endothermic phenomena
- phase changes
- gas expansion

Chapter 5: Review of compression refrigeration (2 weeks)

- thermodynamic compression cycle
- solar refrigeration

Chapter 6: Solar air conditioning (4 weeks)

- air conditioning by "thermal and vortex effect"
- air conditioning by "desiccation/evaporation"
- "Absorption air conditioning" systems
- adsorption air conditioning systems
- installation examples (principle, advantages, disadvantages, etc.)

Assessment method:

Continuous assessment: 100%

Bibliographical references:

1. *Introduction to heat transfer, J. F. SACADURA, Paris, 1978.*
2. *Exercices on heat transfer, M. F. MARINET et al. Course document ENSHMG – Grenoble – France, 1984.*
3. *Heat Transfer, Volume 1: Principles, J. CRABOL, Edition Masson, 1990.*
4. *Heat Transfer, Volume 2: Industrial Applications, J. CRABOL, Masson Publishing, 1990.*
5. *Heat Transfer, Volume 3: Problem Solutions, J. CRABOL, Masson Publishing, 1992.*
6. *Thermal Separation Processes, Principles and Design by Klaus Sattler & Hans Jacob Feindt; VCH edition; ISBN 3-527-28622-5 (Weinheim ...)*
7. *Refrigeration and Air Conditioning from IIT Kharagpur, India; 2008.*

02-

Semester: 3
Teaching unit: UEM 2.1 Subject:
Heat exchangers VHS: 1.5 hours
(22.5 hours of lectures) Credits: 2
Coefficient: 1

Course objectives

It is generally agreed that over 90% of the thermal energy used in industrial processes passes through a heat exchanger at least once. The aim of this course is to calculate and dimension single-phase and two-phase heat exchangers.

The dimensioning of a heat exchanger consists of calculating the exchange surface area required to obtain the desired performance (power, outlet temperature). It is then necessary to determine the pressure drops (pressure losses) that will be caused by the circulation of fluids (due to friction against the walls as a result of viscosity) in order to verify compliance with the specifications, which often impose an upper limit on the value of the pressure drop.

Although there is a wide variety of heat exchangers, four types (shell and tube exchangers, tubular exchangers, finned exchangers, and plate exchangers) will be discussed in detail as they constitute the majority of heat exchangers used in various applications in the field of renewable energy.

Recommended prior knowledge

Advanced fluid mechanics and advanced heat transfer/transport phenomena courses.

Subject matter:

Chapter 1 General information (1 week)

- Definition
- Classification of heat exchangers, Common technologies, Selection criteria,
- Market and applications of heat exchangers

Chapter 2 Characteristic values (4 weeks)

- Local coefficients and overall heat transfer coefficient
- Fouling in heat exchangers
- Orders of magnitude of exchange and fouling coefficients
- Main parameters (temperatures, heat capacity flow rates
- DTLM, efficiency, NUT,
- Fluid flow direction: co-current, counter-current, cross-current
- Intensification of heat exchange: finned surfaces (asymmetry of local coefficients, constant cross-section, efficiency, performance, correlations of finned surfaces.

Chapter 3 Study of heat exchangers (5 weeks)

- temperature changes, exchanged power,
- The ΔT_{ML} correction factor, phase change, etc.
- Main types of exchangers (counter-current exchangers, co-current exchangers, loop exchangers, cross-current exchangers
- Phase change exchangers:
- Condensers (use, different types of condensers, parameters, exchange coefficients)

- Evaporators (exchange coefficients, types of evaporators, assembly)

Chapter 4: Heat exchanger sizing (SSP software) (5 weeks)

- Getting started with SSP software
- Tubular exchangers
- tube and shell heat exchangers
- Finned heat exchangers
- Plate heat exchangers

Assessment method:

Examination: 100%.

Bibliographical references:

- 1- A. LEONTIEV, *Theory of Heat and Mass Transfer* – Mir Publishing House, Moscow.
- 2- J.F. SACADURA *Introduction to Heat Transfer – Technique et Documentation* – Paris.
- 3- H.W. Mac Addams, *Heat Transfer* – Dunod– Paris.
- 4- F. P. INCROPERA, D. P. DEWITT - *Fundamentals of Heat and Mass Transfer* - Wiley, N.Y. – 2002.
- 5- A. Bontemps, A. Garrigue, C. Goubier, J. Huetz, C. Marvillet, P. Mercier and R. Vidil – *Heat Exchangers – Engineering Techniques, Energy Engineering Treatise*.
- 6- E. Rouland, *Heat Exchangers Course, Department of Mechanical Engineering, University of Rouen, 2012, France*.
- 7- Kuppan Thulukkanam, *Heat Exchanger Design Handbook, Second Edition, CRC Press Taylor and Francis Group, 2013*.
- 8- R. K. Shah and D. P. Sekulic, *Fundamentals of Heat Exchanger Design, Wiley, N.Y. – 2003*.
- 9- M. Bennajah and N. Chaouni, *Heat Exchanger Technology and Design, Technip Publishing, 2014*.

01-

Semester: 3
Teaching unit: UEM 2.1
Subject 4: Technical and economic study of ER project management VHS: 45 hours (Lectures: 1.5 hours, Practical work: 1.5 hours)
Credits: 4
Coefficient: 2

Teaching objectives:

Acquire technical and economic knowledge and skills in project management renewable energies and energy efficiency, describe the state of the art in renewable technologies, analyse the economic aspects associated with these technologies, use methodological tools to implement projects. Analysis of the current context and rational use of energy. Concepts of global parameters for energy management. Solutions to be implemented.

Recommended prior knowledge:

Knowledge of renewable energies, energy efficiency, and mathematical concepts in optimisation (linear and non-linear with constraints).

Course content:

Chapter 1: Energy management	(2 weeks)
<ul style="list-style-type: none"> - energy consumption issues - Energy policy - Laws and regulations 	
Chapter 2: Pre-feasibility study	(3 weeks)
<ul style="list-style-type: none"> - Methodology Monitoring - load curves and billing 	
Chapter 3: Pre-dimensioning study	(3 weeks)
Chapter 4: ER project management – basic concepts	(3 weeks)
Chapter 5: Project management and technical and economic analysis	(4 weeks)
<ul style="list-style-type: none"> - Operating principles and cost analysis - Set-up and financing - economic approach - Case study and energy efficiency 	

Assessment method:

Continuous assessment: 40%, Examination: 60%.

Bibliographical references:

- 1- Aidan Duffy, Martin Rogers and LacourAyompe, *Renewable Energy and Energy Efficiency: Assessment of Projects and Policies*, Wiley-Blackwell, 2015.
- 2- D. Yogi Goswami, Frank Kreith, *Handbook of Energy Efficiency and Renewable Energy*, CRC Press, 2007.
- 3- Albert Thumann, Terry Niehus and William J. Younger. *Handbook of Energy Audits*, Taylor & Francis, 2013.
- 4- Finnerty, J. D. (ed), *Analysis and Financing of Renewable Energy Projects*, in *Project Financing: Asset-Based Financial Engineering, Third Edition*, John Wiley & Sons, Inc., Hoboken, NJ, USA, 2012.

Semester: 3

Teaching unit: UET 2.1

Subject 1: Documentary research and dissertation design VHS:

22.5 hours (Lectures: 1.5 hours)

Credits: 1

Coefficient: 1

Teaching objectives:

To provide students with the tools they need to research useful information for their final year project. To help them through the various stages involved in writing a scientific paper. To emphasise the importance of communication and teach them how to present their work in a rigorous and educational manner.

Recommended prior knowledge:

Writing methodology, presentation methodology.

Course content:

Part I: Documentary research:

Chapter I-1: Definition of the subject (2 weeks)

- Subject title
- List of keywords related to the topic
- Gather basic information (acquisition of specialised vocabulary, meaning of terms, linguistic definition)
- Information sought
- Assessing your knowledge in the field

Chapter I-2: Selecting sources of information (02 Weeks)

- Type of documents (books, theses, dissertations, journal articles, conference proceedings, audiovisual documents, etc.)
- Type of resources (libraries, Internet, etc.)
- Assessing the quality and relevance of information sources

Chapter I-3: Locating documents (01 Week)

- Search techniques
- Search operators

Chapter I-4: Processing information (02 Weeks)

- Organising your work
- Initial questions
- Summary of selected documents
- Links between different parts
- Final plan for documentary research

Chapter I-5: Presentation of the bibliography (01 Week)

- Systems for presenting a bibliography (Harvard system, Vancouver system, mixed system, etc.)
- Presentation of documents.
- Citing sources

Part II: Thesis design

Chapter II-1: Thesis outline and stages (02 Weeks)

- Identifying and defining the topic (Abstract)
- Thesis issues and objectives
- Other useful sections (Acknowledgements, List of abbreviations, etc.)
- The introduction (*Write the introduction last*)
- State of the art
- Formulation of hypotheses
- Methodology
- Results
- Discussion
- Recommendations
- Conclusion and outlook
- Table of contents
- Bibliography
- Appendices

Chapter II-2: Writing techniques and standards (02 Weeks)

- Formatting. Numbering of chapters, figures and tables.
- The title page
- Typography and punctuation
- Writing. Scientific language: style, grammar, syntax.
- Spelling. Improvement of general linguistic skills in terms of comprehension and expression.
- Saving, securing and archiving data.

Chapter II-3: Workshop: Critical analysis of a manuscript (01 Week)

Chapter II-4: Oral presentations and defences (01 Week)

- How to present a poster
- How to present an oral communication.
- Defending a dissertation

Chapter II-5: How to avoid plagiarism? (01 Week)

(Formulas, sentences, illustrations, graphs, data, statistics, etc.)

- Quotations
- Paraphrasing
- Provide the complete bibliographic reference

Assessment method:

Examination: 100%

Bibliographical references:

1. M. Griselin et al., *Guide de la communication écrite, 2nd edition, Dunod, 1999.*
2. J.L. Lebrun, *Practical Guide to Scientific Writing: How to Write for the International Scientific Reader, Les Ulis, EDP Sciences, 2007.*
3. A. Mallender Tanner, *ABC of Technical Writing: User Manuals, Instructions for Use, Online Help, Dunod, 2002.*
4. M. Greuter, *Writing Your Dissertation or Internship Report, L'Etudiant, 2007.*
5. M. Boeglin, *Reading and Writing at University: From Chaos of Ideas to Structured Text, L'Etudiant, 2005.*

6. *M. Beaud, The Art of the Thesis, Editions Casbah, 1999.*
7. *M. Beaud, The Art of Writing a Thesis, La découverte, 2003.*
8. *M. Kalika, The Master's Thesis, Dunod, 2005.*

Semester: 3

Teaching unit: UET 2.1 Subject 1:

Reverse Engineering

VHS: 45 hours (Lectures: 1.5 hours and

Workshops: 1.5 hours) Credits: 2

Coefficient: 2

Teaching objectives:

- Understand the principles and objectives of Reverse Engineering (RE) in the field of science and technology (ST).
- Become familiar with RE tools and methods in the relevant speciality.
- Appreciate the value and ethics of RE principles in product design, manufacturing and quality assurance.
- Encourage critical thinking, technical curiosity, reasoned reverse engineering and innovation.
- Learn to analyse, document and model an existing system without initial documentation.

Targeted skills

- Break down and analyse an existing system.
- Accurately reproduce a technical diagram or 3D model from an existing product,
- Apply diagnostic and simulation tools,
- Work in a group on an exploratory project,
- Identify the legal limitations of reverse engineering

Adaptability to specialisations in the field of Science and Technology:

- All specialisations in the ST field are concerned, as follows
- Examples of tasks: Digital technical documentation, technology watch results, technical project management, collaboration on plans, report analysis, understanding industrial processes, production data monitoring, reporting techniques, prototyping, testing)

Prerequisites:

- Fundamental knowledge in the speciality.

Course content:

1. Introduction to reverse engineering

- History, legal and ethical issues of RE
- Definitions and fields of application: Approaches (hardware, software, processes, etc.)
- Fields: maintenance, remanufacturing, cybersecurity, competitive intelligence

2. General methodology

- Analysis of a black box system
- Functional decomposition
- Block diagrams, inputs/outputs, energy or information flows

3. Hardware reverse engineering

- Electronic cards: visual inspection, component identification
- Use of tools: multimeter, oscilloscope, logic analyser
- Recognition of electrical diagrams,
- Reconstruction of diagrams in KiCad / Proteus

4. Software reverse engineering

- Static analysis of binaries (e.g. .exe, .hex, .bin)
- Decompilation, disassembly (introduction to Ghidra, IDA Free, or Hopper)
- Behaviour observation: sniffing, monitoring (e.g. Wireshark)
- Microcontrollers: flash memory reading, firmware extraction

5. Mechanical reverse engineering

- 3D scanning: scanner, manual measurements
- Reproduction of CAD models from existing parts
- Software used: SolidWorks, Fusion360

6. Security and intrusion detection

- Reverse engineering in cybersecurity: malware detection, vulnerabilities
- Software signing, protections against RE (obfuscation, encryption)

7. Real-world case studies

- Analysis of an obsolete or unknown product (mouse, power supply, Bluetooth module, etc.)
- Example of reverse engineering of a mechanical part or simple system (fan, case)

Practical work examples (based on the 4 engineering disciplines)

- **Electrical Engineering:**
 - Reverse engineering of an electronic module without a diagram
 - Example: Bluetooth module, time delay relay
 - Objectives: identify how it works, draw a diagram, propose an improved version.
 - Identification of components (ICs, transistors, resistors, etc.).
 - Use of tools: multimeter, oscilloscope, logic analyser.
 - Reading and extracting firmware from a microcontroller.
 - Introduction to electronic counterfeit detection.
- **Mechanical Engineering:**
 - Reverse engineering of a simple mechanism
 - Examples: manual pump, torque wrench, mini-press, etc.
 - Mechanical disassembly of a system (pump, gear, cylinder, etc.).
 - Measurements and reconstruction of plans or 3D models using CAD software (SolidWorks, Fusion360).
 - Identification of materials and manufacturing methods.
 - Functional simulation based on the recreated model.
- **Civil engineering:**
 - Analysis of existing structures without plans (walls, slabs, structures, etc.).
 - Examples: metal staircase, window sill, formwork)
 - Study and reverse engineering of an existing structural element.

- Identification of materials, assemblies and constraints.
- Modelling of the structure using Revit, AutoCAD or SketchUp.
- Study of the rehabilitation or reproduction of old structural elements.

- **Process engineering:**
 - Reverse engineering of a laboratory module
 - Examples: instruments, distillation, filtration, heat exchangers, simple reactors, etc.
 - Analysis of existing industrial systems (distillation column, exchanger, reactor, etc.).
 - Reconstruction of PFD and PID diagrams based on observation of an installation.
 - Identification of sensors, actuators, control devices.
 - Study of material/energy flows in a process.

Assessment method:

- Technical practical work
- Mini reverse engineering project (report + defence)
- Final examination (multiple-choice questions + case study)

- Examination: 60% Practical work: 40%

Bibliographical references:

- Reverse Engineering for Beginners – Dennis Yurichev (free online)
- The IDA Pro Book – Chris Eagle (software)
- Practical Reverse Engineering – Bruce Dang
- Documentation:
 - <https://ghidra-sre.org>
 - <https://www.kicad.org>
 - <https://www.autodesk.com/products/fusion-360>

IV- Detailed programmes by subject

From Some Discovery ECTS (S1, S2, S3)

Semester: X
Teaching unit: UED X.X
Subject: Transfer techniques applied to drying VHS: 1h30
(22h30 course)
Credits: 1
Coefficient: 1

Teaching objectives:

Knowledge of the characteristics of wet bodies, Mollier diagrams, various drying methods and related balances, as well as some industrial process diagrams and their descriptions.

Recommended prior knowledge:

Basic concepts of thermodynamics, fluid mechanics and heat transfer.

Course content

- Concepts, processes and examples **(1 week)**
- Characteristics of wet products, moisture migration **(2 weeks)**
- Properties of wet gases: the h-X diagram **(2 weeks)**
- Mass and energy transfer in convective drying **(1 week)**
- Drying kinetics, drying process, drying time **(1 week)**
- Convection drying: drying gas and heat required, steps in energy saving, various methods of convection drying **(1 week)**
- Contact drying **(1 week)**
- Radiation drying **(1 week)**
- Dielectric drying **(1 week)**
- Freeze drying or sublimation drying **(1 week)**
- Dryer design: overview of dryers, selection and design **(3 weeks)**

Assessment method:

Examination: 100 %.

Bibliographical references:

- 1- *Thermal Separation Processes, Principles and Design* by Klaus Sattler & Hans Jacob Feindt; VCH edition; ISBN 3-527-28622-5 (Weinheim ...)
- 2- Baert J-P., 1999. *Agri-food. Engineering techniques. F100: Vol. Process Engineering.*
- 3- Bimbenet J.J., 1998. *Conceptual bases of food processing engineering. Engineering techniques, F1000, 19 p.*
- 4- Bonazzi C. and Bimbenet J.J., 2008. *Drying of food -equipment and applications. Techniques de l'Ingénieur, Paris, France, F3002.*
- 5- Brennan J. G., 2006. *Food processing handbook. Edited by: WILEY-VCH Verlag GmbH & Co KGaA, Weinheim, Germany, 602p.*
- 6- Cakmak G. and Yildiz C., 2010. *The drying kinetics of seeded grapes in solar dryers with PCM-based solar integrated collectors. Food and bioproducts processing.*
- 7- Cengel Y.A., 2002. *Heat transfer: A practical approach. Second edition. Ed: McGraw-Hill Science/Engineering/Math, 896p.*
- 8- Charreau A. and Cavaillé R., 2003. *Drying: Theory and Calculations. Techniques del'ingenieur, J2480: Vol. Process Engineering.*
- 9- Fellows P., 2000. *Food processing technology principles and practice. CRC press, New York, 571p*

- 10- Gautier M., 1987. *Fruit growing. Volume 1. Ed: Tec et Doc., Paris, 492p.*
- 11- Mafard P., 1996. *Food industrial engineering. Second edition, Tec et Doc., Volume 1, Paris, 335p.*
- 12- Mujumdar S., 2006. *Handbook of industrial drying. Ed by Taylor & Francis Group, LLC. Singapore: 631p.*
- 13- Ann Charlotte from *Déshyrateur.org* 2009: <http://deshydrateur.org/tout-savoir-sur-la-conservation-des-aliments/>

Semester: X
Teaching unit: UED X.X
Subject: Inverse Techniques
VHS: 1.5 hours (22.5 hours of lectures) Credits: 1
Coefficient: 1

Teaching objectives:

Acquire the skills to identify the key parameters of the process under study based on careful observation of a phenomenon.

Recommended prior knowledge:

Basic knowledge of mathematics (optimisation, Laplace transforms, Fourier transforms, etc.)

Course content:

- Estimation theory **(5 weeks)**
 Observation strategies for optimal signal acquisition
 - Experiment planning
 - Optimal design of experiments
 - Sensitivity analysis
 - Data filtering

- Identification of parametric models **(3 weeks)**
 - Optimizers
 - General minimisation algorithms

- Inverse problem solving in thermal engineering **(7 weeks)**
 - Modelling and inverse problems
 - Ill-posed problems
 - Model reduction
 - Flash methods and parameter estimation

Assessment method:

Examination: 100%.

Bibliographical references:

1. Helcio R.B. Orlande, Olivier Fudym, Denis Mailliet and Renato M. Cotta, *Thermal Measurements and Inverse Techniques*, CRC Press, 2011.
2. S.P. Venkateshan, *Computational Methods in Engineering*, Ane Books Pvt. Ltd., 2016.
3. G.R. Liu and X. Han, *Computational Inverse Techniques in Nondestructive Evaluation*, CRC Press, 2003.
4. Moura Neto, Francisco Duarte, Silva Neto and Antônio José, *An Introduction to Inverse Problems with Applications*, Springer Edition, 2013.

Semester: X
Teaching unit: UED X.X Subject:
Marine Energy
VHS: 1h30 (22h30 course)
Credits: 1
Coefficient: 1

Teaching objectives:

To learn about renewable *hydroelectric and marine* energy sources, *and to understand the technology and equipment used.*

Recommended prior knowledge:

General hydraulics, turbomachinery

Course content:

- Presentation of issues (1 week)
- Techniques, necessary conditions and potential (8 weeks)
- Impact assessment (6 weeks)

Assessment method:

Examination: 100%.

Bibliographical references:

E.S. Cassedy and P.Z. Grossman, Introduction to Energy: Resources, Technology and Society, Cambridge University Press, UK 1998.

Semester: X
Teaching unit: UED X.X
Subject: Fundamentals of Aerodynamics and Turbomachinery VHS: 1.5 hours (22.5 hours of lectures)
Credits: 1
Coefficient: 1

Teaching objectives:

The first part of the course introduces students to the physical phenomena that facilitate understanding of aerodynamics. The focus is mainly on fundamental physical and theoretical concepts, as well as on the classical methodologies used to predict drag and lift on subsonic profiles of lifting wings or turbomachinery.

The second part of the course familiarises students with the main types of turbomachinery and their characteristics. It provides students with the theoretical basis of energy transfer in turbomachinery and an overview of the design methods used for these machines in various sectors.

Recommended prior knowledge:

Applied thermodynamics - fluid mechanics - gas dynamics

Course content:

PART 1: AERODYNAMICS

(8 weeks)

- Moving bodies or moving fluids
- Origins of drag forces
- Dimensionless coefficient
- Forces and moments exerted on the profile
- Thin profiles, Glauert method
- Aerodynamics of wind turbines
- Finite span profile, boundary vortices
- Theory of the lifting line

PART 2: TURBOMACHINERY

(7 weeks)

- **GENERAL INFORMATION ON TURBOMACHINES:** introduction - classification of turbomachines - presentation of flow and equations of motion - velocity triangles, energy exchange mechanisms: exchange between moving blades and fluid, work exchanged when passing through the rotor - indicated work.
- **SIMILARITY OF TURBOMACHINES:** dimensional analysis - machines with similar operation - representation of machine characteristics - limitations of similarity laws - influence of the Reynolds number - scale effect
- **BLOWERS AND FANS:** description - flow characteristics - pressure diagram - actual characteristics: characteristic curve, rotating separation - types of fans
- **CENTRIFUGAL PUMPS:** description - installation on a circuit - components: distributor, impeller, diffuser and volute - flow structure in the impeller: radial pumps, velocity triangles - operating characteristics: actual operation: operating conditions - energy losses, actual characteristics.
- **THEORETICAL CONCEPTS RELATING TO WIND TURBINES:** Wind - Betz theory - Effects of rotation - Taking into account the propeller blade element - Prandtl and Glauert corrections - Optimal blade sizing for maximum power

Assessment method:

Examination: 100%.

Bibliographical references:

- 1-FAURE, Th. *Applied fluid dynamics. Applications to aerodynamics*. 2008, Dunod, Paris.
- 2-J. COUSTEIX *Aerodynamics, turbulence and boundary layer*, 1989, Cépadues éditions
- 3-J. COUSTEIX *Aerodynamics, laminar boundary layer*, Cépadues éditions, 1989)
- 4-PARASCHIVOIU, *Subsonic Aerodynamics*, 1998, Éditions de l'École Polytechnique de Montréal.
- 5-ANDERSON, Jr, J.D, *Fundamentals of Aerodynamics*. 3rdedition. 2001. McGraw Hill, Columbus.
- 6-BERTIN & CUMMINGS *Aerodynamics for Engineers*. 2008, 5th edition. Prentice Hall.
- 7-ENGINEERING TECHNIQUE, Volume B4, *Hydraulic and Thermal Machinery*
- 8-R. OUZIAUX, *Applied Fluid Mechanics, Volume II*, Dunod, Paris
- 9-KRYSINSKI, JAN, *Turbomachines: General Theory / Jan Kryszynski*. - Algiers: Office Des Publications Universitaires, 1986. -
- 10- PLUVIOSE, MICHEL, *Turbomachinery Engineering: Circuits, Blades, Vibrations, Transient Effects... and Solved Exercises* - Paris: Ellipses, 2003.
- 11- SEDILLE, MARCEL, *Hydraulic and Thermal Turbomachinery 2, Centrifugal and Axial Pumps, Hydraulic Turbines* - Paris: Masson, 1967.
- 12- SEDILLE, MARCEL, *Hydraulic and Thermal Turbomachinery 3, Technical Thermodynamics* - Paris: Masson, 1969.
- 13- HANSEN, M. O. *Aerodynamics of Wind Turbines*, 2008, Second Edition. Earthscan Edition.

Semester: X
Teaching unit: UED X.X
Subject: Solar Towers and Chimneys VHS:
22.5 hours (Lectures: 1.5 hours)
Credits: 1
Coefficient: 1

Teaching objectives:

This course aims to introduce students to the different configurations of solar chimneys and to study their thermal behaviour and operating principles.

Recommended prior knowledge:

Heat transfer, Fluid mechanics, Numerical methods, Solar energy.

Course content:

- | | |
|--------------------------------------------------------|------------------|
| 1. Definition Solar chimney | (1 week) |
| 2. Different solar chimney configurations | (1 week) |
| 3. Solar chimneys and sustainable architecture | (2 weeks) |
| 4. Solar chimney power plants | (2 weeks) |
| 5. Solar energy resources and solar chimneys | (2 weeks) |
| 6. How a solar chimney power plant works | (2 weeks) |
| 7. Study of the thermal behaviour of the solar chimney | (2 weeks) |
| 8. Advantages and disadvantages | (1 week) |
| 9. Industrial achievements, projects and prototypes | (2 weeks) |

Assessment method:

Examination: 100%.

Bibliographical references:

- 01- *Energy performance: heating, DHW, electricity, ventilation*, Author(s): CSTB Collective, Publisher(s): CSTB 2016.
- 02- *Energy and climate engineering, Heating, cooling, air conditioning* Author(s): Horst Herr Publisher(s): Dunod 2013.
- 03- *Building energy efficiency*, Author(s): Richard Franck, Guy Jover, Frank Hovorka Publisher(s): Eyrolles 2014.
- 04- *Air Solar Collectors*, Author(s): Guy Isabel Publisher(s): Eyrolles 2014.
- 05- *Integrating Energy into Development Projects*, Author(s): HESPUL Publisher(s): Le Moniteur 2015.

Semester: X
Teaching unit: UED X.X Subject:
Regulations and Standards VHS: 1.5
hours (22.5 hours of lectures)
Credits: 1
Coefficient: 1

Teaching objectives:

An energy efficiency check (compliance check) applicable to new buildings, appliances and motor vehicles is required by law.

The implementation of the law on energy management is based mainly on the National Energy Management Programme (PNME), a medium-term programme. The actions and projects included in the PNME are carried out with the support of the national energy management fund, whose main role will be to stimulate the energy management market. Energy efficiency projects could benefit from financial, tax and customs advantages.

Recommended prior knowledge:

A good level of French

Subject content

- Specific regulatory framework, (1 week)
- Energy efficiency and energy saving standards and requirements governing new buildings and structures, as well as appliances powered by electricity, gas and petroleum products (3 weeks)
- Thermal Regulations in Buildings (2 weeks)
- Energy efficiency and energy saving standards and requirements (2 weeks)
- Energy efficiency, labelling system, certification.
- Energy efficiency monitoring (2 weeks)
- Energy audit (2 weeks)
- Awareness and financing of energy management (1 week)
- Incentives (1 week)
- Coordination of actions, monitoring and sanctions (1 week)

Assessment method:

Examination: 100%.

Bibliographical references:

1. *Krarti Moncef and Marchio Dominique, Technical Guide to Energy Auditing, Presse des Mines, 2016.*
2. *P. A. Bernard, L'audit Energétique, Editions Eyrolles, 1995.*

Semester: X
Teaching unit: UED X.X
Subject: Energy Audit VHS:
1.5 hours (22.5 hours of
lectures) Credits: 1
Coefficient: 1

Course objectives

To enable students to familiarise themselves with the methodology of choice and decision-making in the field of energy in order to carry out a high-quality energy audit.

To carry out an energy audit, it is necessary to distinguish between:

- The tools for carrying out diagnostics
- The people who will carry out the diagnosis, interpret the results and propose solutions for improvement
- The overall approaches (diagnosis, analysis, improvement, renovation, etc.) that certify quality after work and sometimes include criteria other than energy.

Recommended prior knowledge:

Subject content:

Chapter 1: Introduction to audits (2 weeks)

General information, definitions and terminology

Chapter 2: Energy audit methodology (2 weeks)

- Definition of an energy audit
- Main objectives of an energy audit
- Stages of an energy audit

Chapter 3: Diagnostics (5 weeks)

- *Diagnostic tools*
 - Energy performance diagnosis (DPE)
 - Infiltrometry (measuring the airtightness of a dwelling)
 - Thermal imaging camera (thermography)
- *Thermal calculation methods*
 - TH-C-E ex calculation method
 - Dynamic thermal simulation
 - Other calculation methods
- *Carrying out diagnostics and audits*
 - Energy advisor
 - Energy renovation expert ERE
 - Energy performance professional (company)
 - Eco artisan: Overall thermal assessment of a dwelling, renovation advice, works and quality control
 - Energy renovation procedures

Chapter 4: Standard Energy Audit Report Template (4 weeks)

- Essential data for conducting a high-quality audit
- Various important points of the study:
 - Objectives of the audit.

- Presentation of the building's characteristics.
- Energy consumption analysis
- Presentation of recommendations and scenarios.
- Various analyses and conclusions from the study.
- *Summary sheet*
 - Name of the building,
 - Its activity,
 - Its characteristics (volume, surface area, etc.),
 - Its location,
 - Energy sources used in the building and consumption,
 - Energy label of the building,
 - Building assessment,
 - Recommended improvements.

Chapter 5: Case study

(2 weeks)

Mini projects presented orally by students

Assessment method:

Examination: 100%.

Bibliographical references:

- 01- Zariffa (Sohel), *Methodological Guide to Energy Diagnostics in Buildings, Energy Institute of French-speaking Countries, March 1993, Specifications for Building Energy Audits, ADEME, July 2007*
- 02- Joffre, *Solar Thermal Energy in Buildings – Solar Water Heaters, Techniques del'Ingénieur, BE 9-164, October 2004*
- 03- Scientific and Technical Centre for Building (CSTB), *Monthly Method for Evaluating the Thermal Performance of Solar Domestic Hot Water Production Systems, CSTB Notebook, No. 2847, November 1995*
- 04- K. Pennycook, *A BSRIA Guide – Rules of thumb – Guidelines for building services, UK^{4th} edition, The Chameleon Press Ltd, ISBN: 0-86022-626-3, August 2003.*
- 05- *Official Journal of the Algerian Republic No. 84 29, Executive Decree No. 05-495 of 24 Dhou El Kaada 1426, corresponding to 26 December 2005, relating to energy audits of large energy-consuming establishments.*