International Master's Degree in ElectroAcoustics

Syllabus

Bruno Gazengel

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Contents

Part I

Course description

General description

The International Master's Degree in ElectroAcoustics offers students the possibility to learn the fundamentals in electroacoustics and in related fields. The program offers a specialized education in:

- electroacoustics
- mechanics and materials
- transducers (loudspeakers, microphones)
- acoustic loads and acoustic radiation
- real time signal processing

The master's program prepares students for careers dealing with different aspects of electroacoustics which require strong analytical and research skills, whether in the public or private sectors and for PhD studies or research activities.

Organisation of courses

The courses are organized in four Semesters:

1. Semester 1 enables to discover Acoustics & Electroacoustics. First month (September) is dedicated to Refresher Courses.
2. Semester 2 enables to strengthen your skills, especially by doing the first year project.
3. Semester 3 is dedicated to professional courses dealing with electroacoustics and to the second year project (during which you can meet professionals).
4. Semester 4 enables to apply your knowledge during a 5 months internship in a company or a laboratory.

Part II

Course Contents

Chapter 1

Semester 1: Discover Acoustics & Electroacoustics

1.1 Acoustics I

Coordinator Guillaume Penelet

Expected skills & knowledge The main objective of this course is that students have solid backgrounds on fundamental aspects of acoustics including

- The fundamental equations of acoustics (backgrounds in fluid mechanics and thermodynamics)
- The derivation of the wave equation (mostly for the usual case of uniform fluids at rest)
- The acoustics of the gas column (resonance, free oscillations, coupling etc..)
- Reflection, transmission, and diffraction phenomena
- Guided waves and the modal theory
- Spherical and cylindrical waves (sound radiation, diffraction, guided waves in cylindrical ducts, etc...)

Pre requisite Having backgrounds in acoustics is obviously a good point, but it is not essential. Having solid backgrounds in mathematics is essential. This includes : trigonometry, integration/derivation, asymptotic expansions of usual functions, solving of O.D.E., functions of multiple variables, vector analysis and operators (in various systems of coordinates) , linear algebra ... Reminders of useful formula will be provided, and exercise will be treated, but you need to know that we can't ignore mathematics in this course...

Contents Four lectures (around 10 hours) and four series of exercises related to each lecture (around 30 hours). The titles of lecture are (see lecture notes on UMTICE for more details)

- Fundamental equations of acoustics (in fluids)
- Plane waves
- Cylindrical and spherical waves.
- Guided waves
- Modal analysis

Work duration 60 hours (48h tutorial, 12h practical), personal work estimated to be 30 hours

Exam type Written exam (1 written exam at mid-part weight 1, and 1 final exam weight 2)

Exam duration 1 hour (exam 1) and 2 hours (exam 2)

Docs for exam Personal notes allowed ☒, lecture notes ☒, all documents allowed ☐, no documents allowed ☐

Credits 6 ECTS

Literature References

- A.D. Pierce, "Acoustics, an introduction to its physical principles and applications" chapters 1, 3-5, et 7
- C. Potel, M. Bruneau, "Acoustique Générale", chapters 1, 3-6 (in French)
- S. Temkin, ""Elements of Acoustics"", chapters 1-4"

On-line course Acoustics I UMTICE Course

1.2 Room Acoustics I

Coordinator Christophe Ayrault

Expected skills & knowledge

- Be able to understand the physical phenomena involved in the sound propagation in a room.
- Know the acoustical objective and subjective criteria which describe a room.
- Be able to to control the room acoustics by passive materials.
- Be able to measure the room characteristics.
- Be able to build a numerical model of a room.

Pre requisite Notions in acoustics an instrumentation

Contents

- Room modelling : statistical models, geometrical models, modal behaviour
- Objective and subjective criteria
- Measurement of reverberation time and objective criteria from impulse response (RT, STI, C80, D50)
- Introduction to Catt Acoustics software

Work duration 34 hours (22h tutorial, 12h practical), personal work estimated to be 10 hours

Exam type Written exam, practical reports.

Exam duration 2 hours

Docs for exam No documents allowed

Credits 3 ECTS

Literature References

- KUTTRUFF, Heinrich. Room acoustics. Crc Press, 2016.
- CREMER, Lothar et MÜLLER, Helmut A. Principles and applications of room acoustics. Vol.1 & 2. Chapman & Hall, 1982.
- BARRON, Michael. Auditorium acoustics and architectural design. Routledge, 2009.
- COX, Trevor J. et D'ANTONIO, Peter. Acoustic absorbers and diffusers: theory, design and application. Crc Press, 2009.
- BERANEK, Leo. Concert halls and opera houses: music, acoustics, and architecture. Springer Science & Business Media, 2012.

On-line course Room Acoustics UMTICE Course

1.3 Vibrations I

Coordinator Frédéric Ablitzer

Expected skills & knowledge To know the basic concepts in vibrations of discrete and continuous systems, in particular how to obtain the eigenmodes and use them to calculate solutions for free and forced vibrations problems

Pre requisite Basic bachelor knowledge

Contents

- Vibrations of undamped and damped SDOF systems: free response, forced response)
- Vibrations of MDOF systems: eigenmodes, free and forced responses using modal superposition
- Vibrations of continuous systems (strings, bars, membranes): eigenmodes, free and forced responses using modal superposition

Work duration 20 hours (tutorial), personal work estimated to be 8 hours

Exams

- 1 intermediate written exam without document (1h30)
- 1 final written exam with documents (2 hours)

Credits 2 ECTS

Literature References

- S. Rao, Mechanical vibrations, Paris, Prentice Hall , 2011
- Leonard Meirovitch, Principles and techniques of vibrations, New Jersey : Prentice Hall , 1997
- S. Graham Kelly, Mechanical vibrations : theory and applications, Stamford : Cengage Learning , cop. 2012

On-line course UMTICE page

1.4 Maths for Acoustics I

Coordinator Olivier Dazel

Expected skills & knowledge

- Expected skills
  - Advanced Matrix calculus
  - Main basis of analytical resolutions methods for finite and infinite number of degrees of freedom problems (in 1D, 2D and 3D)
  - Techniques of projection (Inner-products, modes)
  - Notions on finite difference schemes: truncation error, order of accuracy, spectral accuracy, and grid resolution.
- Expected knowledge
  - Be able to find the analytical expression of simple and more advanced 1D acoustic problems (strings, beams and cavities of various shapes and boundary conditions)
  - Be able to construct standard finite-difference schemes (temporal and spatial).
  - Be able to control the accuracy of a finite difference approximation by selecting the scheme and the grid for 1D acoustic problems.

Pre requisite Starter courses (maths), especially Matrix manipulation, Calculus and Integration

Contents Lectures and exercises divided in 6 chapters:

- Introduction: Which problems do we want to solve ?
- Finite dof systems: Mass-spring
- Continuous systems: Strings, Acoustic cavities; beams, 2D and 3D problems
- Strategies (analytical/numerical) to solve these problems
- Matrices (Key properties of matrices, Exponential and Transfer Matrices, Key matrix factorisation techniques)
- N degrees of freedom systems (Exponential Matrix / Transfer matrix, Modes of a finite-degree of freedom system, Resolution)
- Inner Euclidean and Hilbert Spaces (Definition, Inner products and physical systems)

Work duration 30 hours tutorial, personal work estimated to be 10 hours

Exam type Written exam.

Exam duration 2 hours

Docs for exam Personal notes allowed (except correction of exercises).

Credits 3 ECTS

Literature References

- G. Strang, Introduction à l'algèbre linéaire, Ecole Polytechnique De Montreal, 2015

On-line course Maths for Acoustics UMTICE Course

1.5 Instrumentation Basics

Coordinator Bertrand Lihoreau

Expected skills & knowledge

- Be able to measure the characteristics of an acoustic system (spectrum analysis, transfer function analysis)
- Be able to estimate the uncertainty on an acoustic measurement

Pre requisite Use of typical measurement systems (generator, oscilloscope).

Contents

- Development of a basic soundmeter level
- Loudspeaker transfer functions measurement (electrical impedance, pressure response)
- Estimation of uncertainties for acoustical measurements.

Work duration 10 hours (practical), personal work estimated to be 10 hours

Exam type Written exam □, oral exam □, MCQ □, practical exam ☒, practical report □

Exam duration 2 hours

Docs for exam Personal notes allowed □, lecture notes □, all documents allowed ☒, no documents allowed □

Credits 1 ECTS

Literature References

- Dominique Placko, Fundamentals of Instrumentation and Measurement, John Wiley & Sons, 1 mars 2013 - 532 pages
- Jacob Fraden, Handbook of Modern Sensors: Physics, Designs, and Applications, Springer Science & Business Media, 22 sept. 2010 - 663 pages
- MICHAEL SAYER, ABHAI MANSINGH, MEASUREMENT, INSTRUMENTATION AND EXPERIMENT DESIGN IN PHYSICS AND ENGINEERING, PHI Learning Pvt. Ltd., 1 janv. 1999 - 380 pages
- Charles P. Wright, Applied Measurement Engineering: How to Design Effective Mechanical Measurement Systems, Prentice Hall PTR, 1995 - 402 pages
- Bob Metzler, Audio Measurement Handbook, Audio Precision, 1993 - 178 pages

On-line course Instrumentation Basics Course

1.6 Electronics Basics

Coordinators Vincent Colin, Issa Ouattara

Expected skills & knowledge

- Be able to make a simulation and to measure the response of an analog electrical network (passive loudspeaker filter)
- Be able to make a simulation and to measure the response of an analog active network using Op. Amp (active loudspeaker filter)

These lessons are for anyone who has a basic understanding of electronics concepts, but who wants to understand the operation of components found in the most common discrete circuits. The topics of these lessons focus on circuits that are the building blocks for many common electronics devices, and on the very few important principles you need in working with electronics.

Pre requisite These lessons assume that you have some knowledge of basic electronics such as Ohm's law and current flow.

Contents

- Tutorials
  - DC Review – This section provides a review on the basic concepts, components, and calculations that are useful when working with direct current (DC) circuits.
  - Diodes – Here you learn about the diodes, including how to use the diode in DC circuits, the main characteristics of diodes, and calculations you can use to determine current, voltage and power.
  - RC circuits – This section examines the basic concepts and equations for RC circuits. You discover how to use resistors, capacitors and diodes for DC/AC circuits, and learn related calculations for time and frequency analysis.
  - Operational Amplifiers - You explore the use of operational amplifiers to amplify electrical signals. You also learn how to build active filters, which pass or block AC signals in a band of frequency around the resonant frequency of the circuit.
- Practical work
  - Simulation of systems using LT Spice (passive filter, active filter, envelope detector)
  - Implementation and measurement of the systems

Work duration 24 hours (12h tutorial, 12h practical), personal work estimated to be 24 hours

Exam type Written exam, practical report

Exam duration 2 hours

Docs for exam Personal notes NOT allowed, Lecture notes NOT allowed

Credits 2.5 ECTS

Literature References H. Kybett and E. Boysen. All New Electronics Self-Teaching Guide, Wiley Publishing, Inc. Third Edition, 2008.

On-line course No online course. Electronics Basics ESEO, provided by the teacher (printed version only)

1.7 Signal I

Coordinator Laurent Simon

Expected skills & knowledge The objectives of this course are as follows :

- to know the main basic tools of signal processing,
- to know how to apply the tools dedicated to digital signal processing using the Python language (for both deterministic and random data)

Pre requisite This course covers all the knowledge and skills of the undergraduate cycle, as well as openings towards the Signal 2 course (next semester). The backgrounds in mathematics mostly include: calculation of integrals (for Fourier transform calculation), calculation of discrete summations (for Discrete Fourier transform calculation) and tools for random data (probability and statistics).

Contents This teaching is organized in the form of 6 sessions of 3-3.5 hours each, each session consisting of a quick presentation of the course, theoretical exercises and practical exercises. 4 thematic blocks are proposed:

- temporal tools (including time-shifting, convolution and correlation operations)
- frequency analysis tools (Fourier transforms for continuous and discrete time signals)
- analysis of time-invariant linear systems, filtering
- introduction to multi-sensor analysis

Work duration 20 hours (8h tutorial, 12h practical), personal work estimated to be 20 hours

Exam type

- Session 1:
  - Test for the Practicals (setting in situation, analysis of real-world data, codes to write...)
  - Written test
- Session 2: written test

Exam duration 2 hours for all tests/exams

Docs for exam Personal notes and personal codes

Credits 2 ECTS

Literature References

- Discrete-Time Signal Processing, Oppenheim, Schafer, Pearson, 2010
- Signals, Systems and Inference, Oppenhaim, Verghese, Pearson, 2016

On-line course Signal Processing 1 (UMTICE page)

1.8 Python for Audio

Coordinator Bertrand Lihoreau

Expected skills & knowledge Be able to use the Python software for simple audio processing (time domain analysis, frequency domain analysis)

Pre requisite

Contents

- Time domain computing: Matlab basics and manipulation of sound waves, sound envelopes and synchronous detection
- Frequency domain: Spectral analysis, direct and inverse Fourier transforms, frequency resolution, windowing, spectrograms.
- Musical sounds: analysis & Synthesis of musical sounds
- Mini Project: simulation of a microphone pair recording and writing of flanging effect function.

Work duration 24 hours (practical), personal work estimated to be 10 hours
Practical exam

Exam duration 2 hours

Docs for exam All documents allowed

Credits 2.5 ECTS

Literature References

- Ian McLoughlin, Applied Speech and Audio Processing: With Matlab Examples, Cambridge University Press, 19 févr. 2009 - 206 pages
- Theodoros Giannakopoulos, Aggelos Pikrakis, Introduction to Audio Analysis: A MATLAB® Approach, Academic Press, 15 févr. 2014 - 288 pages
- Alexander D. Poularikas, Understanding Digital Signal Processing with MATLAB® and Solutions, CRC Press, 13 nov. 2017 - 455 pages

On-line course Python for Audio UMTICE Course

1.9 Transducers Basics

Coordinator Bruno Gazengel Manuel Melon

Expected skills & knowledge

- Expected knowledge
  - know the usual characteristics of an electroacoustic chain
  - know what is lumped elements modelling
  - know the equivalent components describing and mechanical and acoustical behaviour
  - Know the technical characteristics of microphones.
  - Be able to choose a microphone according to the datasheet.
  - Be able to model (sensitivity) an electrodynamic omnidirectional microphone.
- Expected Skills. Be able to:

- model an electroacoustic system with an analytical approach and equivalent circuits
- analyze a mechanical system and represent the equivalent electrical diagram.
- calculate analytically the response of a mechanical system
- analyze an acoustical system and represent the equivalent electrical diagram
- calculate analytically the response of an acoustical system
- draw an equivalent network to the usual couplings (electromechanical, electroacoustic)
- draw an equivalent network to an electrodynamic transducer
- calculate analytically the response (efficiency, sensitivity) of an electrodynamic transducer

Pre requisite Basis in electronics, acoustics and vibration

Contents

- Lecture + tutorial
  - Audio Systems Characterisation
  - Lumped Elements modelling of Mechanical systems (1 DOF, 2 DOF)
  - Lumped Elements modelling of Acoustical systems (open or closed duct, radiation)
  - Equivalent circuits for coupling (electricity to mechanics and mechanics to acoustics)
  - Lumped Elements modelling of an electrodynamic shaker
  - Lumped Elements modelling of an electrodynamic loudspeaker on infinite baffle"
  - Microphone directivity (membrane & sound interaction)
  - Recording microphones (mono, stereo, multichannel)
  - Electrodynamic microphones (pressure microphone, ribbon microphone, unidirectional microphone)
- Practicals
  - Experimental characterisation of simple mechanical systems
  - Experimental characterisation of simple acosutical systems
  - Measurement of loudspeaker parameters

Work duration 32 hours (30h tutorial, 12h practical), personal work estimated to be 30 hours

Exam type Written exam, practical exam

Exam duration 2 hours

Docs for exam Personal notes allowed □, lecture notes □, all documents allowed □, no documents allowed ☒

Credits 4 ECTS

Literature References

- Leo L. Beranek, Tim Mellow, sound fields and transducers, Academic Press, 2012
- Mendel Kleiner, Electroacoustics, Taylor & Francis, 2013
- Martin Colloms, High Performance Loudspeakers, Wiley, 2005, 6th Edition
- Joseph D'Appolito, Testing Loudspeakers , Audio Amateur Press, 1998
- Mario Rossi, Audio, Presses Universitaires Polytechniques
- Ray A. Rayburn, Eargle's The Microphone Book: From Mono to Stereo to Surround - A Guide to Microphone Design and Application, Taylor & Francis, 12 nov. 2012 - 466 pages
- Glen Ballou, Electroacoustic Devices: Microphones and Loudspeakers, Taylor & Francis, 10 sept. 2012 - 328 pages

On-line course Transducers Basics Course

1.10 Loudspeaker system

Coordinator Bruno Gazengel, Manuel Melon

Expected skills & knowledge

- Know the different loudspeaker systems types (active, passive)
- Know the different electrical filter types
- Know the different acoustic loads
- Be able to model a loudspeaker system (sealed & vent enclosure, passive filters)

Pre requisite Transducers basics

Contents

- Usual loudspeaker systems (active, passive)
- Usual electrical filters
- Lumped elements models a usual loudspeaker systems (sealed enclosure, vented enclosure) with equivalent networks.
- Measurement of loudspeaker systems characteristics (sealed enclosure, vented enclosure).

Work duration 40 hours (28h tutorial, 12h practical), personal work estimated to be 25 hours

Exam type Written exam, practical report (mini-project).

Exam duration 2 hours (written exam)

Docs for exam Personal notes allowed □, lecture notes □, all documents allowed □, no documents allowed ⊠ (written exam)

Credits 5 ECTS

Literature References

- Leo L. Beranek, Tim Mellow, sound fields and transducers, Academic Press, 2012
- Mendel Kleiner, Electroacoustics, Taylor & Francis, 2013
- Martin Colloms, High Performance Loudspeakers, Wiley, 2005, 6th Edition
- Joseph D'Appolito, Testing Loudspeakers , Audio Amateur Press, 1998
- Mario Rossi, Audio, Presses Universitaires Polytechniques (in French), 2007

On-line course Loudspeaker System Course

Chapter 2

Semester 2: Strengthen your skills

2.1 Green's functions

Coordinator Olivier Richoux

Expected skills & knowledge

- Knowledge:
  - Green's function theory
  - integral formalism in time and frequency domain
- Skills - be able to write and use the Green's function in usual cases:
  - Free space (1d to 3d)
  - reflecting boundaries and image sources
  - use the integral formalism in different simple applications :
  - Acoustic field in small cavity
  - Acoustic field between two infinite wall
  - Sound radiation by a flat piston

Pre requisite Acoustics I

Contents

1. INTRODUCTION
   (a) Non homogeneous differential equations: various examples in physics
   (b) Toolbox
      i. Linear differential operator
      ii. Boundary conditions
      iii. Fourier transform
      iv. Green's identities
      v. Dirac distribution
2. TIME-INDEPENDENT PROBLEM
   (a) Definition of the Green's function
   (b) Interpretation
   (c) Homogeneous Boundary Conditions
   (d) Reciprocity
   (e) Solution

i. Method of Variations of Parameters
ii. Sturm-Liouville Problem
iii. Eigenmode Expansion
iv. Direct Method

3. 3D (and 2D) free space Green's function
    (a) Integral Formalism in Acoustics
    (b) Introduction
    (c) Green's theorem
    (d) Integral formalism in time domain
    (e) Integral formalism in frequency domain
    (f) Solving integral equations
    (g) Boundary conditions
    (h) Examples of application

Work duration 20 hours (10h tutorial, 10h practical), personal work estimated to be 20 hours

Exam type Written exam ☒, oral exam ☐, MCQ ☐, practical exam ☐, practical report ☐

Exam duration 2 hours

Docs for exam Personal notes allowed ☐ , all documents allowed ☐, no documents allowed ☒

Credits 3 ECTS

Literature References

- Alastuey, A., Clusel, M., Magro, M., & Pujol, P. (2015). Physics and Mathematical Tools: Methods and Examples. World Scientific Publishing Company.
- Duffy, D. G. (2001). Green's Functions with Applications. Chapman & Hall.

On-line course Acoustics II UMTICE Course

2.2 Transmission Lines

Coordinator Jean-Pierre Dalmont

Expected skills & knowledge Be able to model a transmission line (duct, horn) thanks to telegraph equation and matrix formalism

Pre requisite Acoustics I, transducers basics, loudspeaker systems

Contents

- General concepts on transmission lines.
- Equations of acoustic transmission lines without and with viscothermal effects.
- Transfer Matrix and impedance calculation.
- Effect of higher order modes.
- Measurement techniques of acoustic wave guides.

Work duration 20 hours (tutorial), personal work estimated to be 10 hours

Exam type Written exam ☒, oral exam ☐, MCQ ☐, practical exam ☐, practical report ☐

Exam duration 2 hours

Docs for exam Personal notes allowed ☐ , all documents allowed ☐, no documents allowed ☒

Credits 2 ECTS

Literature References

- Munjal, M. L. (2014). Acoustics of ducts and mufflers. John Wiley & Sons.

On-line course

- Transmission Lines UMTICE Course

2.3 Vibrations Experiments

Coordinator Frédéric Ablitzer

Expected skills & knowledge To be able to perform vibration measurements and modal analysis on realistic structures.

Pre requisite Starter courses (vibrations), vibrations I

Contents

- Lectures
  - Modal analysis principles
- Practicals
  - Modal analysis
  - Operating deflection shapes of a plate
  - Free vibrations of a string
  - Experimental modal analysis

Work duration 20 hours (8h tutorial, 12h practical), personal work estimated to be 10 hours

Exam type Practical reports

Exam duration NA

Docs for exam NA

Credits 2 ECTS

Literature References

- Ewins D.J., Modal testing : theory, practice, and application, Wiley , 2000
- Avitabile Peter, Modal testing : a practitioner's guide, Wiley : SEM 2018
- J. He and Z.F. Fu, Modal Analysis, Butterworth Heinemann (2001)
- Bruel & Kjaer, Structural Testing Part 1, Mechanical Mobility Measurements
- Bruel & Kjaer, Structural Testing Part 2, Modal analysis and simulation

On-line course

- UMTICE On line course
- On line course NPTEL

2.4 Sound Perception

Coordinator Bruno Gazengel

Expected skills & knowledge

- Know the basics od sound perception
- Be able to design simple perceptive tests and to use statistical analysis tools (ANOVA, PCA, ...)

Pre requisite None

Contents

- Auditory system, pitch perception, frequency perception (masking, auditory filters), intensity perception, applications to industrial problems
- Sound space perception, Analysis of auditory scenes
- Design of listening tests, statistical analysis of experimental results, examples on perceptive evaluation of loudspeakers

Work duration 20 hours (lectures), personal work estimated to be 10 hours

Exam type Written exam

Exam duration 2 hours

Docs for exam Personal notes allowed ☒ , all documents allowed ☐, no documents allowed ☐

Credits 2.5 ECTS

Literature References

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On-line course

2.5 Signal II

Coordinator Laurent Simon

Expected skills & knowledge

- Expected knowledge
  - Know the basics of digital filtering
  - Know the basic tools of non-stationary signal analysis (Short-time Fourier Transform, wavelet analysis, Wigner-Ville distribution)
  - Know the basic acoustic imaging method
- Expected skills
  - Be able to design simple FIR and IIR filters
  - Be able to apply them in a context of real-world data, in order to extract informations from data
  - Be able to write beamforming and Nearfield Acoustic Holography (NAH) codes

Pre requisite Starter courses (signal)

Contents

1. Digital Filtering
   (a) Introduction, properties of digital filters
   (b) Analog systems simulation (IIR filters). Discrete-time approximation of loudspeaker behavior (practical)
   (c) FIR filters design. Filtering with FIR Filters (practical)
2. Non stationary signal analysis
   (a) Introduction : stationarity vs non-stationarity, global ideas about time-frequency analysis, examples
   (b) Limits of Fourier analysis and introduction to local Fourier analysis : classical Fourier transform (including time-frequency duality), Short-Time Fourier transform (definition, interpretation, limits)
   (c) Frequencies : Instantaneous frequency, analytic signal, examples (favourable and unfavourable cases)
   (d) Decompositions and densities : atomic decompositions (including wavelet analysis), densities (including Wigner-Ville decomposition)
3. Acoustic Imaging
   - Acoustic intensimetry and beamforming
   - Nearfield Acoustic Holography (NAH) in cartesian coordinates
   - Loudspeaker measurement with microphone arrays

Work duration 24 hours (12h lecture, 12h tutorial-practical), personal work estimated to be 20 hours

Exam type Written exam ☒, oral exam ☐, MCQ ☐, practical exam ☐, practical report ☒

Exam duration 2 hours

Docs for exam Personal notes allowed ☒ , all documents allowed ☐, no documents allowed ☐

Credits 2 ECTS

Literature References

- Edward P. Cunningham, Digital filtering : an introduction, New York : J. Wiley , 1995
- Time-Frequency Analysis, L. Cohen, Prentice-Hall, 1995
- Time-Frequency / Time-Scale Analysis, P. Flandrin, Academic Press, 1999
- A Wavelet Tour in Signal Processing, S. Mallat, 3rd Ed., Academic Press, 2009

On-line course Signal Analysis I UMTICE Course

2.6 Digital Filtering

Coordinator Antonin Novak

Expected skills & knowledge Be able to design and implement FIR and IIR filters for delayed and real time signal processing

Pre requisite Signal Analysis I

Contents

1. Delayed digital filtering: two-ways speaker system simulation
   (a) Electrical filters simulation with IIR
   (b) Loudspeakers simulation with IIR
   (c) Acoustic propagation simulation with FIR
   (d) Complete two-ways system simulation and auralisation
   (e) Complementary work (effect of acoustic enclosure, effect of voice coil impedance, effect of piston directivity)
2. Real time digital filtering
   (a) Introduction, Digital Filters Refresh
   (b) Building a Parametric Equalizer
   (c) Nonlinear Audio Effects
   (d) Introduction to DSP Sigma Studio with ADAU1701
   (e) 2h practical on Sigma Studio DSP

Work duration 26 hours (tutorial), personal work estimated to be 25 hours

Exam type Written exam ⊠, oral exam □, MCQ □, practical exam □, practical report ⊠

Exam duration 2 hours

Docs for exam Personal notes allowed □ , all documents allowed ⊠, no documents allowed □

Credits 3 ECTS

Literature References

- Digital filtering: discrete-Time signal processing, Oppenheim and Schafer, Prentice Hall, 2nd edition, 1999
- Digital filtering: an introduction, Edward P. Cunningham, New York : J. Wiley , 1995

On-line course Digital Filtering UMTICE Course

2.7 Digital Electronics

Coordinator Samuel Poiraud

Expected skills & knowledge

- Expected knowledge
  - Basics about digital
  - Basics about ADC et DAC architectures
  - Basics about digital devices
- Expected skills. Be able to:
  - Evaluate the performances of an ADC (or DAC)
  - Choose and digital architecture

Pre requisite Electronics basics, Instrumentation basics

Contents

- Introduction to digital electronics, digital signal processing, devices, IDE (integrated development environment).
- SNR measurement, analysis of noise, interest of oversampling.

Work duration 6 hours (lecture + tutorial) + 4 hours (practicals), personal work estimated to 3 hours

Exam type Written exam + practical report

Exam duration 1 hour 30

Docs for exam no documents allowed

Credits 1 ECTS

Literature References

- D. Genet – Programmable logic basics – Groupe ESEO, 2005.
- C. Marven & G. Ewers – A simple approach to digital signal processing – Texas Instruments, 1993.
- U. Zölzer & al. – Digital Audio Effects (Second Edition) – 2011.
- G. Torres – How analog-to-digital converter works – Hardware secrets, Apr. 2006

On-line course Digital Electronics Basics ESEO Course (internal access only)

2.8 Low Power Analog Electronics

Coordinator Jérôme Tissier

Expected skills & knowledge

- Be able to design an amplifier (class A, B, AB) using BJT transistors in common-emitter and common collector mode.
- Be able to design an audio amplifier using an integrated audio power amplifier and to calculate the heat-sink for power dissipation
- Be able to build and measure an audio amplifier

Pre requisite electronics basics and starter courses (mathematics)

Contents

1. Tutorial (10h)
   - BJT transistors,
   - Common-emitter BJT transistor : class A amplifier,
   - Common-collector BJT transistor (Push-Pull) : class B and AB amplifier,
   - Heat-sink for power dissipation,
   - Integrated audio power amplifier.
2. Practical (21h), audio amplifier design
   - voltage amplifier circuit,
   - current amplifier circuit ,
   - Push-Pull circuit,
   - complete system : voltage amplifier+current amplifier+feedback
   - cabling, test, measurement and debug function by function,
   - test and measurement of the complete system.

Work duration 31 hours (10h tutorial, 21h practical), personal work estimated to be 15 hours

Exam type written exam (tutorial part) and practical exam (evaluation in practical sessions)

Exam duration 2 hours

Docs for exam no documents allowed

Credits 3 ECTS

Literature References

- P. HOROWIST, W. HILL. “The art of electronic”, Cambridge university press.
- M. GIRARD, “Amplificateurs de puissance” , McGraw-Hill
- Internet course (in French)

On-line course LP Analog Electronics ESEO online course

2.9 Electrodynamic motors

Coordinator Bruno Gazengel

Expected skills & knowledge

- Know the basics of magnetism
- Know the physics of an electrodynamic motor
- Be able to model an electrodynamic motor using a FEM software

Pre requisite

Contents

1. Basics of magnetism
   (a) Magnetic field (demonstration of magnetic field, sources of magnetic field, mathematical representation of magnetic field)
   (b) Electromagnetism: the phenomena associated with electric and magnetic fields and their interactions with each other and with electric charges and currents.
   (c) Magnetic materials (Magnetic moment, Atomic origin of magnetism, Magnetic material model: Amperian model, Magnetization and magnetic fields quantities,Reaction of magnetic materials submitted to an external magnetic field: Susceptibility and permeability, demagnetizing field)
   (d) Ferromagnetic materials (Classification of magnetic materials: diamagnetic, paramagnetic and ferromagnetic. Domain structure, Magnetization process: hysteresis loop, Soft and hard ferromagnetic materials, Design of permanent magnet: load line and, working point, Evershed's criterion)
2. Application of magnetism to loudspeaker motor design
   (a) Part 1: magnetostatics (Recap of magnetic materials characteristics, Loudspeaker motor structure, Circuit analogy, From Maxwell's equations to design principles, Examples)
   (b) Part 2: voice coil design (Parameters in voice coil design, Goals and constraints, Worked example)
3. 2D FEM modelling of motors (with free software FEMM)

Work duration 24 hours (12h tutorial, 12h practical), personal work estimated to be 6 hours

Exam type Written exam ☐, oral exam ☐, MCQ ☒, practical exam ☒, practical report ☐

Exam duration 2 hours

Docs for exam Personal notes allowed ☐ , all documents allowed ☐, no documents allowed ☒

Credits 2.5 ECTS

Literature References

- Magnetism I & II, E. du Trémolet de Lacheisserie, PUG, 1999 (in French)
- Introduction to solid state physics, Ch. Kittel, Wiley, 2004
- Solid state physics , N. Ashcroft et D. Mermin , EDP Sciences
- Magnetism and magnetic materials, J.M.D. Coey, Cambridge edition
- Peter Campbell, "Permanent Magnet Materials and their Application", Cambridge University Press, 1996

On-line course Electrodynamic Motors UMTICE Course

2.10 CAD modelling

Coordinator Mathieu Gaborit

Expected skills & knowledge Be able to use a CAD software (SolidWorks)

Pre requisite None

Contents Basic principles and SolidWorks user interface, introduction to sketching, modeling simple parts (prismatic and revolution), use of advanced solid features (rehearsal, shells and ribs, scans, ...), use of drawings, upward assembly.

Work duration 20 hours (tutorial), personal work estimated to be 5 to 20 hours depending on abilities.

Exam type Practical on a CAD software, part design, assembly and sheet formats.

Exam duration 2h (typical), 3h (if the parts are difficult)

Docs for exam All.

Credits 2 ECTS

Literature References None

On-line course CAD Modelling UMTICE Course

2.11 Project

Coordinator Bruno Gazengel

Expected skills & knowledge Be able to design, model, build and measure an audio prototype using a limited budget

Pre requisite All first year courses

Contents

1. First phase
   (a) Bibliographic research
   (b) Design of the prototype (number of transducers, transducer type, acoustic load type, electrical filter type)
   (c) First simulations based on Lumped Elements Models (Akabak,...)
   (d) **First oral presentation**
2. Second phase
   (a) Sketch of the mechanical part of the system (with a CAD software)
   (b) Improved simulation of the acoustic response
   (c) Validation of the mechanical design
   (d) **First report and second oral presentation**
3. Third phase
   (a) Design of the filters
   (b) Building of the system
   (c) Measurement of the system and comparison with simulations
   (d) **Final report and final oral presentation**

Work duration 60 hours (practical), personal work estimated to be 200 hours

Exam type Written exam □, oral exam ⊠, MCQ □, practical exam □, practical report □

Exam duration 20 min

Docs for exam Personal notes allowed □ , all documents allowed ⊠, no documents allowed □

Credits 7 ECTS

Literature References Past projects reports

On-line course First year project UMTICE Course

Chapter 3

Semester 3: Meet the professionals

3.1 3D sound and sound field synthesis

Coordinator Manuel Melon

Expected skills & knowledge

- Know the auditory perception cues
- Know the different techniques for 3D sound
- Know how to control the sound field in a defined region

Pre requisite

Contents

- Spatial perception (how the auditory system localizes sounds), stereophony and multichannel audio
- Binaural technology, Holophony and WaveField Synthesis, Ambisonics and Higher Order Ambisonics
- Principle of sound zones controls

Work duration 20 hours (12h lecture, 8h practical), personal work estimated to be 8 hours

Exam type written exam (MCQ)

Exam duration 2 hours

Docs for exam Personal notes allowed □, lecture notes □, all documents allowed □, no documents allowed ⊠

Credits 2 ECTS

Literature References

- Jens Ahrens, Analytic Methods of Sound Field Synthesis, Springer Science & Business Media, 25 janv. 2012 - 300 pages
- Rozenn Nicol, Binaural Technology, Audio Engineering Society, 2010 - 77 pages
- Roginska de Agnieszka, Paul Geluso, Immersive Sound: The Art and Science of Binaural and Multi-Channel Audio, Audio Engineering Society, 2017

- Jens Blauert, The Technology of Binaural Listening, Springer Science & Business Media, 7 juin 2013 - 511 pages

On-line course 3D Sound UMTICE Course

3.2 Numerical Vibroacoustics

Coordinator Frédéric Ablitzer

Expected skills & knowledge Be able to use Boundary Elements Modelling and Finite Elements Modelling software (ABEC, COMSOL) for simple applications.

Pre requisite

Contents

- Introduction of BEM principles. Introduction to ABEC (Acoustic Boundary Element Calculator). Study of simple cases
- Simple models of acoustics in closed and opened systems by FEM and/or BEM approaches with Comsol. Computation of vibrations modes for structures and acoustic modes for closed cavities by FEM, vibroacoustic coupling on the solid / fluid interface, Applications to more complex systems.

Work duration 36 hours, personal work estimated to be 12 hours

Exam type Written exam □, oral exam □, MCQ □, practical exam ⊠, practical report □

Exam duration 2 hours

Docs for exam Personal notes allowed □ , all documents allowed ⊠ , no documents allowed □

Credits 3 ECTS

Literature References web page COMSOL Application Gallery

On-line course UMTICE Course

3.3 Signal III

Coordinator Laurent Simonw

Expected skills & knowledge The aim of this course is to study the main principles of time domain signal processing including adaptive filters, for post processing and real time applications.

Pre requisite Digital filtering

Contents

1. Introduction to time domain signal processing (10 h tutorial)
   - From frequency domain (FRF) to time domain (impulse response) processing
   - Introduction to deterministic and random signals, stochastic and ergodic process
2. Adaptive Filtering (12 h tutorial, 8h practical)
   - Linear combiner with desired response: optimal solution
   - Wiener adaptive filters for identification, inverse modeling, prediction and noise reduction.
   - LMS algorithms for adaptive FIR filters
   - Introduction to Kalman Filters
   - Audio applications of Wiener and Kalman Filter
3. Application to a simple case (10h project): realisation of a echo canceller

Work duration 40 hours (22 h tutorial, 18h practical), personal work estimated to be 20 hours

Exam type Written exam ☒, oral exam ☒, MCQ ☐, practical exam ☐, practical report ☐

Exam duration 2 hours

Docs for exam Lectures notes, documentation provided by the teacher

Credits 4 ECTS

Literature References

- Adaptive Signal Processing , Bernard Widrow and Samuel D. Stearns , Prentice-Hall, 1985
- Adaptive Filter Theory, Simon Haykin, Prentice-Hall, 1991

On-line course TO COMPLETE

3.4 Power electronics

Coordinator Eric Chauveau

Expected skills & knowledge

- Know the basics of switching in power electronics
- Know the constitution of class D audio amplifier
- Understand the effects of amplifier sub-functions on his quality
- Be able to measure electrical engineering values
- Be able to simulate a power electronic bridge

Pre requisite

- Electronics Basics §2.7
- Loudspeaker system §1.10
- Low Power Analog Electronics §2.8
- Basis of dynamic systems, regulation, and automation in closed loop

Contents

- Overview of power electronics
  - Switching as amplification
  - Modulation and demodulation
  - Passive filtering
- Power amplifiers design
  - Switching transistors (MOSFETs)
  - Transistor drivers
  - Power supply specifications
  - Feedback loop consideration
- Electronic power bridge behavior
  - Electronic simulation software
  - Simulation with real components models
  - Effect of parasitic elements
  - Evolutions of sub-functions
- Amplifier performances
  - Analysis of amplifier setup
  - Signal quality estimation
  - Efficiency measurements

Work duration 21 hours (14h tutorial, 7h practical), personal work estimated to be 10 hours

Exam type Written exam □, oral exam □, MCQ ⊠, practical exam □, practical report ⊠ (a possibility to consider. . .)

Exam duration 1h30

Docs for exam Personal notes allowed □, lecture notes □, all documents allowed □, no documents allowed ⊠

Credits 2 ECTS

Literature References

- J. Honda, M. Rodriguez et J. Cerezo, “IRAUDAMP5 - 120w x 2 channel Class D audio power amplifier using the IRS2092S and IRF6645”, International Rectifier, may 2011.
- N. Mohan, T. M. Undeland, et W. P. Robbins, “Power electronics: converters, applications, and design”, 2. ed., New York, Wiley, 1995.
- R. Jeffs et P. Mathews, “Commercializing Class D Amplifier Technologies”, in Audio Engineering Society Conference: 27th International Conference: Efficient Audio Power Amplification, 2005.
- M. Piou, “Chapitre 10 Energie et puissance électrique”, in Les lois de l’électricité. Régimes continu, sinusoïdal, triphasé, transitoire. Cours et exercices corrigés. Electricité générale - niveau A, Ellipses., 2010, p. 264.

On-line course Power Electronics online course en ESEO platform

3.5 Loudspeaker modeling

Coordinator Bruno Gazengel

Expected skills & knowledge

- Be able to model analytically the main non linearities (Le, Bl, Cms)
- Be able to model analytically thermal effects in a loudspeaker
- Be able to make model the loudspeaker radiation taking into account modal vibration
- Be able to make a simulation of a non linear loudspeaker (electrical and mechanical parts)
- Be able to make an auralization of non linear loudspeakers

Pre requisite Transducers basics, Loudspeaker systems, materials for loudspeaker

Contents

1. Lumped parameter modelling and measurement, state space modelling of linear systems (Loudspeaker, loudspeaker in vented box)
2. Modelling of non linear effects in loudspeakers. Study of THD and IMD. State space modelling of nonlinear loudspeaker
3. Physical causes and nonlinear symptoms, Diagnostics on regular large signal performance, Diagnostics on irregular loudspeaker defects, Power Handling, Heating, Aging, Climate, Meaningful Loudspeaker Specifications

Work duration 30 hours (14h lecture, 10h tutorial, 6h practical), personal work estimated to be 12 hours

Exam type Written exam □, oral exam □, MCQ ⊠, practical exam □, practical report □

Exam duration 2 hours

Docs for exam Personal notes allowed □ , all documents allowed □, no documents allowed ⊠

Credits 2.5 ECTS

Literature References

- Klippel, Wolfgang. Tutorial: Loudspeaker nonlinearities—Causes, parameters, symptoms. Journal of the Audio Engineering Society 54.10 (2006): 907-939.
- Klippel, Wolfgang. ""Nonlinear modeling of the heat transfer in loudspeakers. Journal of the Audio Engineering Society 52.1/2 (2004): 3-25.
- Agerkvist, Finn. Modelling loudspeaker non-linearities. Audio Engineering Society Conference: 32nd International Conference: DSP For Loudspeakers. Audio Engineering Society, 2007.
- Jakobsson, David, and Marcus Larsson. Modelling and compensation of nonlinear loudspeaker (2010).

On-line course Loudspeaker and microphone modelling UMTICE Course

3.6 Material for loudspeakers

Coordinator Manuel Melon

Expected skills & knowledge

- Be able to choose materials (surround, spider, cone) for designing an electrodynamic loudspeaker
- Be able to design a numerical model of a loudspeaker to do a parametric study

Pre requisite Transducers basics, Loudspeaker systems

Contents

1. General concepts about materials : classification of materials, general mechanical properties of materials, elastic and viscoelastic materials, equations of behaviour, experimental characterization techniques (elongation, flexion, Dynamical Mechanical Analysis)
2. Technologies of materials : materials for membranes, materials for motors, materials for suspension, application of materials in loudspeaker design. Examples of design process and measurement techniques. Link between materials and perceptive aspects.
3. FEM simulation of loudspeakers to understand to effect of material properties on acoustic radiation

Work duration 12 hours (6h lecture, 6h practical), personal work estimated to be 6 hours

Exam type Written exam ⊠, oral exam □, MCQ ⊠, practical exam □, practical report □

Exam duration 2 hours

Docs for exam Personal notes allowed □ , all documents allowed □, no documents allowed ⊠

Credits 1 ECTS

Literature References

- Frankort, F. J. M. (1978). Vibration patterns and radiation behavior of loudspeaker cones. Journal of The Audio Engineering Society, 26(9), 609-622.
- Klippel, W., & Schlechter, J. (2006, October). Measurement and visualization of loudspeaker cone vibration. In Audio Engineering Society Convention 121. Audio Engineering Society.
- Klippel, W., & Schlechter, J. (2008, October). Distributed mechanical parameters describing vibration and sound radiation of loudspeaker drive units. In Audio Engineering Society Convention 125. Audio Engineering Society.

On-line course Loudspeaker Technology UMTICE Course

3.7 Mini and micro transducers

Coordinator Pierrick Lotton

Expected skills & knowledge

- Be able to model the response of a headphone
- Be able to model and electrostatic microphone sensitivity taking into account the effect of viscothermal losses

Pre requisite Transducers basics, microphone basics, transmission lines, acoustics I

Contents

1. Headphones
   (a) General models of headphones and earphones (lumped elements model of the loudspeaker, model of the ear)
      i. Introduction
      ii. Classification
      iii. Lumped Elements Modeling (headphone without ear, sealed enclosure, enclosure with leakage)
      iv. Headphone with ear (model of the ear, coupling the headphone with the ear)
   (b) Measurement techniques for mini and micro transducers
      i. Micro-speakers : Dynamic and Balanced Armature - Specifications and measurements
      ii. Two-port modelling
      iii. Measurement hardware : couplers and acquisition systems
   (c) Mini project (measurement ant modelling of a simplified headphone)
2. Microphones
   (a) Generalities on microphones
   (b) Basic modelling of microphones
   (c) Advanced modelling of microphones
   (d) Mini project

Work duration 20 hours (tutorial), personal work estimated to be 16 hours

Exam type Written exam ☒, oral exam ☒, MCQ ☐, practical exam ☐, practical report ☐

Exam duration 2 hours

Docs for exam Personal notes allowed ☒ , all documents allowed ☐, no documents allowed ☐

Credits 2 ECTS

Literature References

- Borwick, J. (Ed.). (2012). Loudspeaker and headphone handbook. CRC Press.
- Beranek, L. L., & Mellow, T. J. (2012). Acoustics: sound fields and transducers. Academic Press.
- Søren Jønsson, Bin Liu, Lars B. Nielsen, Andreas Schuhmacher, Simulation of Couplers, AES, Workshop 7, 2003 March 23rd
- M. Rossi, Audio, Lausanne, Presses Polytechniques et Universitaires Romandes, 2008.
- UNIT “Electroacoustique”
- Z. Skvor, Vibrating Systems and their equivalent circuits, Elsevier 1991

On-line course Mini and micro transducers UMTICE Course

3.8 Radiation of transducers

Coordinator Manuel Melon

Expected skills & knowledge

- Know the solutions (arrays, horns) for directivity control in free field and in rooms
- Be able to model simple systems (arrays, ...) using Matlab

Pre requisite Transducers basics, Loudspeaker technology, acoustics II

Contents

1. Introduction to radiation
2. Elementary electroacoustic sources, principles of arrays, modelling array radiation (Matlab simulation of line array and end-fire array)
3. Effect of baffle on radiation (scattering)
4. Real loudspeaker array and interaction with a room
5. Radiation of horns
6. Radiation of Distributed Mode Loudspeakers

Work duration 35 hours (19h lecture, 8h tutorial, 8h practical), personal work estimated to be 20 hours

Exam type Written exam ☒, oral exam ☐, MCQ ☒, practical exam ☐, practical report ☐

Exam duration 2 hours

Docs for exam Personal notes allowed ☐ , all documents allowed ☐, no documents allowed ☒

Credits 3.5 ECTS

Literature References

- Beranek, L. L., & Mellow, T. J. (2012). Acoustics: sound fields and transducers. Academic Press.
- G.W.J. van Beuningen; E.W. Start; "Optimizing Directivity Properties of DSP Controlled Loudspeaker Arrays", Reproduced Sound 16 Conference, Stratford (UK) 17-19 Nov 2000, Institute of Acoustics.
- M. Boone, W. Cho & J. Ih, "Design of a highly directional endfire loudspeaker array", J. Audio Eng. Soc., 309-25, 382-92 (2009).
- Xavier MEYNIAL , DGRC arrays : A synthesis of geometric and electronic loudspeaker arrays, 120th AES Convention, Paris, 2006 May 20–23, Preprint 6786.
- X. Meynial, G. Grégoire, Design of a passive DGRC column loudspeaker with wave front synthesis, AES 130th Convention, London, UK, 2011 May 13–16.
- M. Ureda, "Analysis of loudspeaker line arrays", J. Audio Eng. Soc., 52, 467-99 (2004).
- Van der Wal, Menno; Start, Evert W. ; de Vries, Diemer, "Design of Logarithmically Spaced Constant-Directivity Transducer Arrays", JAES 44 Number 6 pp. 497-507; June 1996.

On-line course Radiation of Transducers UMTICE Course

3.9 Transducers measurements

Coordinator Antonin Novak

Expected skills & knowledge

- Know the principle of measurement microphones
- Know the usual techniques for microphone calibration
- Be able to develop a measuring test bench using a sound card and a programming software
- Be able to measure different Transducers (microphone, loudspeaker, headphone, earphones) according to the usual standards

Pre requisite Transducers basics, Loudspeaker technology, Matlab for Audio, Signal Analysis I

Contents

1. Microphones measurements techniques (measurement microphone data sheet, relative calibration, absolute calibration)
2. Loudspeakers measurement techniques (advanced approaches in measurements using a sound card and a programming platform, advanced approaches in loudspeaker measurements leading to models at higher levels)
3. Practicals on measurement systems, loudspeakers, headphones and microphones.

Work duration 27 hours (12h lecture, 15h practical), personal work estimated to be 15 hours

Exam type Written exam □, oral exam □, MCQ ⊠, practical exam ⊠, practical report □

Exam duration 2 hours

Docs for exam Personal notes allowed □ , all documents allowed □, no documents allowed ⊠

Credits 3 ECTS

Literature References

- Measurement microphones, Bruel & Kjaer, 1994
- Frederiksen, E. (2013). Acoustic metrology–an overview of calibration methods and their uncertainties. International Journal of Metrology and Quality Engineering, 4(2), 97-107.
- Stan, G. B., Embrechts, J. J., & Archambeau, D. (2002). Comparison of different impulse response measurement techniques. Journal of the Audio Engineering Society, 50(4), 249-262.
- Farina, A. (2000, February). Simultaneous measurement of impulse response and distortion with a swept-sine technique. In Audio Engineering Society Convention 108. Audio Engineering Society.
- Novak, A., Simon, L., Kadlec, F., & Lotton, P. (2010). Nonlinear system identification using exponential swept-sine signal. IEEE Transactions on Instrumentation and Measurement, 59(8), 2220-2229.

- International standard IEC 60268-5, Sound system equipment – Part 5: Loudspeakers
- International standard IEC 60268-7:2010, Sound system equipment - Part 7: Headphones and earphones
- International standard IEC 62458:2010 Sound system equipment - Electroacoustical transducers - Measurement of large signal parameters

On-line course Transducers Measurements UMTICE Course

3.10 Advanced Transducer Project

Coordinator Manuel Melon

Expected skills & knowledge Be able to model and measure an advanced audio system for real life applications or for research applications using previous results given in the literature.

Pre requisite First year courses and project, first semester of second year courses.

Contents

1. Phase 1
   (a) Literature review,
   (b) Analytical and numerical modeling,
   (c) **Intermediate defense**
2. Phase 2
   (a) Experiments on a prototype provided by a laboratory or a company
   (b) Analysis of results, improvement of the prototype
   (c) **Final report and defense**

Work duration 36 hours (practical), personal work estimated to be 100 hours

Exam type Report + oral presentation

Exam duration 30 min

Docs for exam All documents allowed

Credits 6 ECTS

Literature References NA

On-line course Advandced Project UMTICE Course

3.11 Tools for Job searching

Coordinator Manuel Melon

Expected skills & knowledge Be able to write CV and Covering letter (CL) in order to apply for a job in a specific country.

Pre requisite English B2+

Contents

1. Course structure, Brainstorming and Important General Information
2. CV and CL Workshop: Exchange and Help session
3. Job Interview Workshop
4. Communication styles by country and final Assignment
5. Final Session – Job interviews

Work duration 10 hours (tutorial), personal work estimated to be 10 hours

Exam type Writing a CV and a CL according to a job offer.

Exam duration NA

Docs for exam NA

Credits 1 ECTS

Literature References

- Careers and Employability Service, University of Kent
- Eva Newman, Job Searching Tools for You! CreateSpace Independent Publishing Platform, 31 janv. 2016 - 82 pages

On-line course IMDEA Communication UMTICE Course

3.12 Seminars

Coordinator Manuel Melon

Expected skills & knowledge

- Know the different activities performed in different companies
- Be able to build a network of different people working companies

Pre requisite None

Contents Seminars about audio given by academic, industrial or alumni

Exam type None

Credits 0 ECTS

On-line course Seminars Course

Chapter 4

Semester 4: Apply your knowledge

4.1 Numerical modelling of Transducers

Coordinator Manuel Melon

Expected skills & knowledge Be able to model real electroacoustical devices using BEM / FEM softwares (ABEC, COMSOL)

Pre requisite

Contents

- BEM modelling (ABEC) of electroacoustical devices (loudspeaker + load + radiation)
- FEM modelling (COMSOL) of compression chamber loudspeaker

Work duration 40 hours (tutorial), personal work estimated to be 10 hours

Exam type Written exam □, oral exam □, MCQ □, practical exam ⊠, practical report □

Exam duration 2 x 3 hours

Docs for exam Personal notes allowed □ , all documents allowed □, no documents allowed ⊠

Credits 4 ECTS

Literature References

- Roger Pryor, Multiphysics Modeling Using COMSOL?: A First Principles Approach, Jones & Bartlett Learning, 2011 - 852 pages
- Comsol application gallery
- ABEC Software

On-line course Numerical modeling of Transducers UMTICE Course

4.2 Master's thesis

Coordinator Bruno Gazengel

Expected skills & knowledge Be able to apply the skills and knowledge acquired during semesters 1, 2 and 3 during a 5 months internship (in a company or a laboratory)

Pre requisite First and second year courses

Contents NA

Work duration 5 months

Exam type internship report + oral defense

Exam duration 45 min

Docs for exam NA

Credits 26 ECTS

Literature References NA

On-line course NA

Part III

Teachers

Academic Teachers

Professional Teachers