Lascala
Erasmus Mundus Master

Erasmus+

Syllabus Semester 1 University Paris-Saclay

ERASMUS MUNDUS JOINT MASTER DEGREE LASCALA

CONTENT

Year 1 – Semester 1
University Paris-Saclay, France

COURSE SYLLABUS LASCALA master

Course Title: Mathematics and statistical methods
Course Semester: 1rst
Country: France
Number of ECTS: 3

Aims:

This "tool" course teaches how to extract relevant scientific information from experimental and simulated data. Modern statistical methods to handle and analyze big data flows (data mining, multivariate analysis) will be discussed.

Content :

Chapter 1: Statistical tools
From probabilities to statistics
Distribution, pdf, distribution function
Characterization
Matrix algebra

Chapter 2: Big data
What are big data and how to handle them?
How to define information, clustering, discrimination?
Multivariate analysis, characterization, discrimination, inference, decision
How to extract information from random uncertainties, error propagation

Chapter 3: Theory/experiment confrontation
Epistemology, scientific approach/process/hypothesis, validation.
Null hypothesis method
Chi2, Kolmogorov-Smirnov and other tests
The inverse problem, solving methods

Chapter 4: Cause/effect relations
Correlation and cause/effect
Partial correlation
Multiple regression

Chapter 5: Evolving processes
States and transitions
Absorbing processes
Regular processes

Prerequisites:

- basic knowledge of probability and statistics;
- basic knowledge of matrix algebra, eigenvectors/values.

Recommended Books:

- Data-Driven Modeling & Scientific Computation: Methods for Complex Systems & Big Data Paperback – September 15, 2013 by J. Nathan Kutz
- Multivariate Data Analysis (7th Edition) by Joseph F. Hair Jr, William C. Black, Barry J. Babin and Rolph E. Anderson (Feb 23, 2009)

Teaching Staff:

Pierre Désesquelles

Grading System:

100% written exam at the end

Hours:

Lectures 20 hours, Tutorials 10 hours

COURSE SYLLABUS LASCALA master

Course Title: Experiences in laboratories
Course Semester: 1rst
Country: France
Number of ECTS: 6

Aim:

Allow the students to discover experimental work on real platforms inside the laboratories (IJClab, SOLEIL, etc.).

Content:

6 Mini-experiments to be chosen among the following items (2 day work each):

- **Signal processing** (IAS, IEF)
- **Radioactivity and cosmic radiations** (IPN, Iolanda Matea)
- **Platform JANNUS-Orsay** (CSNSM)
  The Platform couples a 2 MV Tandem accelerator (ARAMIS) and a 190 kV ion implantor (IRMA) to a 200 kV Transmission Electron Microscope (TEM FEI Tecnai G2 20).
- **Nuclear Physics with Tandem accelerator** (IPN)
- **Pollution control** (LPG-UVSQ, Pierre Tardiveau, Philippe Bousquet)
- **Superconductivity**: conductivity measurements, quantitative study of flux pinning, SQUID basics
- **Magnetization measurements:** from paramagnetism to superconductivity
- **Electron diffraction and X-ray diffraction** for the study of condensed matter (at SOLEIL)

Prerequisites:

Basic knowledge of experimental physics

Recommended Books:

Teaching Staff:

Researchers from the hosting laboratories

Grading System:

1 ECTS per lab work based on written report and behavior during the lab work itself

Hours:
60 hours lab work + writing the report

Course Title: Quantum Solid State Physics
Course Semester: 1rst
Country: France
Number of ECTS: 8

Aim:

The aim of this course is to provide an introduction and a comprehensive view on modern solid state physics at an undergraduate level from the widespread basics to emergent fields of research which can be tackled at an elementary level (e.g. graphene).

Content:

The course emphasizes the fundamental aspects underlying quantum macroscopic phenomena in solids, which are present in most common materials of our daily life, metals, semiconductors, magnets. Each chapter will be illustrated by on-going research trends and/or applications (superconductivity, LEDs, magnetic memories…).

Prerequisites:

The prerequisites are usually taught at the level of the third year of university. In some cases, Statistical Physics is not. See below.
- Fundamentals of Quantum Mechanics. Book: Quantum Mechanics by C. Cohen-Tannoudi, B. Diu, F. Laloë (vol. I and II), Ed Wiley.
- Fundamentals of Statistical Physics. Book: Statistical Mechanics by K. Huang, Ed Wiley.

Concepts of Statistical Physics needed for this course can be easily learnt in parallel.

Recommended Books:

C. Kittel: Introduction to Solid State Physics (J. Wiley and Sons)
N. W. Ashcroft and D. M. Mermin: Solid State Physics (Brooks and Cole)
H. Alloul: Physics of Electrons in Solids (Springer)
M. T. Dove: Structure and Dynamics (O.U.P)
J. Singleton: Band theory and electronic properties of solids (O.U.P)
S. J. Blundell: Magnetism in condensed matter (O.U.P).

Teaching Staff:

P. Mendels, M. Civelli

Grading System:

Hours:
Lectures 40 hours, Tutorials 30 hours

Course Title: Atoms, Molecules and Optics
Course Semester: 1rst
Country: France
Number of ECTS: 5

Aim:

The physics of atoms and molecules, which constitutes the subject matter of this course rests on a long history of discoveries, both experimental and theoretical. Far from giving a complete account of the historical development, this introductory course aims to give an understanding of both theoretical foundations and key steps, which have occurred in this field.

Content:

As a direct application of quantum mechanics, this course includes materials on basic atomic and molecular physics with discussion on structure, spectra and interaction with electric and magnetic field.
Outline of the lectures:
Introduction : Key steps on electrons, photons and atoms studies Elements of quantum mechanics One-electron atoms : Schrodinger equation for one-electron atoms Special hydrogenic systems Interaction with electromagnetic radiation Fine structure and hyperfine structure Interaction with external fields Many-electron atoms Central field approximation The periodic system of the elements Corrections to the central field approximation : L-S and j-j coupling Interaction with electromagnetic radiation and with static fields Molecular structure The Born-Oppenheimer

Prerequisites:

Basic Quantum mechanics.

Recommended Books:

Teaching Staff:

N. Kebaili, F. Brénétaker

Grading System:

Hours:

Lectures 25 hours, Tutorials 15 hours

COURSE SYLLABUS LASCALA master

Course Title: Particles, Nuclei and Universe
Course Semester: 1rst
Country: France
Number of ECTS: 8

Aim:
This major course offers to learn the basic features about the elementary particles, the fundamental interactions of nature, nuclear structure, nucleosynthesis, stellar evolution and cosmology.

Content:
Chapter 1: Particles and symmetries (GM)
Klein-Gordon equation & Time-dependent perturbation theory
Application to processes with scalar particles
Calculation of basic particle reactions / introducing the Feynman diagrams
Symmetries of particles / reactions (spacetime, internal, gauge)
Experiments: collisions, kinematics and conservation laws

Chapter 2: Hadron synthesis (GM)
The quark model
The main hadron properties
Experimental proofs: partons, colors and gluons
Phenomenology of the hadrons

Chapter 3: The primordial Universe (LV)
I- The distant Universe: Objects and distances, distribution of matter - Evidence for dark matter - The cosmological principle - The expansion law and its recent acceleration - The FLRW metrics and the scale factor R(t)
II- Cosmic evolution: The observational pillars for the Big Bang model - The energy
content of the Universe, the critical density - The Friedmann equations - Applications
III- The building of matter after big-bang Nucleosynthesis of light elements, the neutron-to-proton ratio, baryon density and baryon-to-photon ratio - The recombination, decoupling of matter and radiation

Chapter 4: The nucleus, a unique manybody system (EK)
Dimensionless study of many-body systems
Finite systems, the spin-orbit rule
The case of nuclei: from QCD to the nucleon-nucleon interaction, nuclear

superfluidity
From mean-field to magic numbers, the isospin symmetry, the nuclear chart

Chapter 5: From nuclear states to nuclear dynamics (EK)
Nuclear states: localization
Nuclear spontaneous reactions: more than a dozen of radioactivities
Statistical physics-like approaches: the liquid drop (mass parabola, the alpha radioactivity, fission and fusion)
Probing nuclei, Astronuclei

Chapter 6: Star formation and evolution (LV)
I- From cloud to star: Gravitational instability, cloud fragmentation and Initial mass function - Free fall and hydrostatic evolution - Disk formation
II- A star on the main sequence properties of a star on the main sequence, mass-luminosity relationship- Evolution in the HR diagram - Stellar nucleosynthesis - White dwarf stage

Prerequisites:

Classical mechanics (and Lagrangian formulation if possible)
- Basics in statistical physics
- Quantum mechanics
- Special relativity
- Classical field theory: Maxwell equations (and beyond if possible)

Recommended Books:

- Classical electrodynamics (Jackson)
- Quarks and leptons (Halzen, Martin)
- Quantum mechanics, Vol. 1 & 2 (Cohen-Tannoudji, Diu, Laloe)
- Relativistic quantum mechanics (Greiner)
- Nuclear Physics in a Nutshell (Bertulani)
- The formation of stars (Stahler, Palla)
- Principles of stellar evolution and nucleosynthesis (Clayton)

Teaching Staff:

Elias Khan, Laurent Verstraete, Samuel Wallon

Grading System:

100% written exam

Hours:

40 hours lecture, tutorials 30 hours

COURSE SYLLABUS LASCALA master

Course Title: European History of Science: building European values
Course Semester: 1rst
Country: France
Number of ECTS: 3

Aims:

This course's purpose is to teach international students about the european values of scientific research, epistemology and scientific method. The course will approach the european concept of the use of reason, the Enlightenment philosophy and science's role in the improvement of living conditions in Europe.

Content (including lab trainings, projects, industry visits, etc.):

The course will start by approaching Galileo and the rise of the scientific thought's separation from Church. Students will learn to define the concept of scientific proof. They will be taught a synthetic introduction to the 20th century's History of Europe, particularly through Albert Einstein's life and the role played by european physicists during World War II. The course will also approach the Manhattan Project.

2 of the lecture sessions will be a seminar with a scientist guest.

The students will be presented with 5 different themes. They will team up in groups of 5 or 4 to prepare a project on one of these themes.

The 5 themes will be the following :

- Measuring the speed of light
- The theory of relativity's evolution
- Galileo's theory on the creation of the universe
- Foucault's pendulum
- Finding one's way at sea

Prerequisites:

Recommended Books:

Teaching Staff:
Prof. Daniele Nutarelli

Grading System in % (homework, oral presentation, lab training, mid-term exam, final exam, etc.)
Final oral presentation of the group project

Hours: (Lecture / Tutorial / Practical courses)
8 lecture and team work sessions ; 3 hours/session ; 1 session/week

Course Title: Lasers
Course Semester: 1rst
Country: France
Number of ECTS: 2,5 (mandatory for students who go to Lund and optional for students who go to La Sapienza on the second semester)

Aim:
This course offers an introduction on laser history and laser theory, as well as an understanding of laser resonators, Gaussian beams and the principles of laser amplifiers.

Content:
- Chapter 1: Brief introduction about laser history, coherence properties, main constituents and applications.

- Chapter 2: Laser resonators. The stability of cavities is treated with the ray matrix formalism assuming centered systems and Gauss conditions.

- Chapter 3: Gaussian beams.
Properties of gaussian beams (divergence, waist, phase curvature radius) treated using the complex curvature radius.
Transformation of gaussian beams (ABCD law), in particular by a lens (waist conjugation formula).
Determination of the fundamental gaussian mode parameters as a function of the cavity parameters (case of linear cavities,
symmetric cavities, general case)
Spatial and spectral modes

- Chapter 4: Principles of laser amplifiers
Laser-matter interaction (Absorption, stimulated emission, spontaneous emission)
Transition spectral profile, Einstein coefficients, cross sections
Homogeneous and inhomogeneous spectral broadening
Population rate equation systems, population inversion (2-, 3-, 4- level systems)
Amplification coefficient, Gain
Saturation

- Chapter 5: Introduction to laser theory
Brief overview about the pumping mechanisms
Cavity losses, cavity photon lifetime, threshold

Working conditions in the continuous regime
Output intensity and optimisation of the output coupler
Spatial Hole-burning
single-mode/multimode operation
Pulsed regimes (Mode locking and Q-switching)

Prerequisites:

Recommended Books:

Teaching Staff:

Séverine Boyé-Péronne

Grading System:

Written exam

Hours:

20 hours ; 10 hours lecture & 10 hours tutorial

COURSE SYLLABUS LASCALA master

Course Title: French as a foreign language (FLE)
Course Semester: 1rst
Country: France
Number of ECTS: 3 (optional and non-cumulative with mandatory courses)

Aim:
Allow the students to learn French and discover French culture.

Content:
These lectures are part of a common program for all international masters at Paris Saclay. The students' level is determined on the first session with a short test. They are then divided into different groups: beginner, intermediate, advanced. According to each group's level, the students learn French grammar, vocabulary, idiomatic expressions, customs, etc. Other languages are available for fluent or French-born students.

Prerequisites:

Recommended Books:

Teaching Staff:
Roselyne Debrick

Grading System:
Oral and written exams

Hours:
24 hours lecture

COURSE SYLLABUS LASCALA master

Course Title: Plasma physics and applications
Course Semester: 1rst
Country: France
Number of ECTS: 6 (optional and non-cumulative with mandatory courses)

Aim:

This set of lectures is devoted to an introduction to plasma physics and its applications: in particular, thermonuclear fusion (ITER), space plasmas and plasma discharges, reactors and thrusters.

Content:

Chapter 1:
Basic plasma physics
Characteristic length, velocity and time scales
Collective effects: electric and magnetic screenings
Elementary theory of transport, mobility and diffusion
Element of kinetic theory: Vlasov and Fokker-Planck equations
Wave and instability: ion acoustic wave, electron plasma wave

Chapter 2:
Advanced plasma physics
From a kinetic to a fluid description
MHD equations: derivation and limits, Alfvén theorem and magnetic topology
Magnetic tension, Alfvén and magneto-acoustic waves
Magnetic reconnection: slow and fast, the MRI experiment and space applications
Static equilibrium: cylindrical case and the Grad-Shafranov equation for tokamaks

Chapter 3:
Applied plasma physics
Discharge physics: high pressure, low pressure, breakdown criteria
Thermonuclear reactor and fusion physics
Introduction to capacitive, inductive and microwave reactors
Plasma thrusters and advanced applications

Prerequisites:

Basic knowledge (3rd year level) in classical electrodynamics, statistical physics, fluid mechanics, analytical mechanics and mathematical tools for physics. No major courses are requested to follow this course.

Recommended Books:

- R. J. Goldston & P. H. Rutherford, Introduction to plasma physics, IOP, 1995
- F. F. Chen, Introduction to plasma physics, Plenum, 1974
- J. M. Rax, Physique des plasmas, Dunod, 2005
- S. Galtier, Introduction to modern magnetohydrodynamics, Cambridge, 2016

Teaching Staff:

Sébastien Galtier, Tiberiu Minea, Jean-Marcel Rax

Grading System:

100% written exam

Hours:

24 hours lecture

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