Syllabus
Semester 3
University Paris-Saclay

ERASMUS MUNDUS JOINT MASTER DEGREE LASCALA

université PARIS-SACLAY
SZTE UNIVERSITY OF SZEGED
SAPIENZA UNIVERSITÀ DI ROMA
LUND UNIVERSITY

CONTENT

Year 2 – Semester 3
University Paris-Saclay, France

COURSE SYLLABUS LASCALA master

Course Title: Transverse High Technologies (high vacuum, cryogeny, superconductivity)
Course Semester: 3rd
Country: France
Number of ECTS: 3

Aims: To learn about the physics of high technologies that are commonly used for large scale experiments. State of the art of the techniques to produce extreme conditions of vacuum, cryogeny and superconductivity.

Content :
Cryomagnetism :

-Introduction to the cryomagnetic systems

-Magnetostatics applied to large coil structures

Superconductivity :

-Introduction

-Superconductors for the production of high magnetic fields

-Applications of conductors, superconductors and coils

-Low temperature physics : electrical, thermal and magnetic properties of metals and insulators ; cryogenic fluids

-Thermal stability of the conductors and protection of the superconductor coils in case of a quench

-Installing low temperatures : liquefaction, refrigeration ; measuring low temperatures.

-Vacuum physics: properties of rarefied gazes, thermal transfer under low pressure, interaction with the walls.

Materials :
-Chemical physics and material mechanics
-High thermal flow : introduction to the problematic of the High Temperature Materials ; alloy, steel, ceramic, composites.
-High neutronic flux : behavior of irradiated materials. Geometric evolution ; hardening. Steel embrittlement. Localization of the deformation after an irradiation ; restoring the irradiation defects.

Prerequisites: basic thermodynamics, solid state physics, material physics

Recommended Books:
Introduction to Superconductivity - M. Tinkham
Solid State Physics - N. W. Ashcroft and N. D. Mermin
Applied Superconductivity - P. Seidel

Teaching Staff:
C. Baumier (CNRS-UPS)
F. Chiodi (UPS)

Grading System:
One written examination (/20) for session 1, oral or written examination (/20) for session 2 following the number of students concerned.

Hours:
30 hours in total
20 hours lecture
10 hours tutorials

Course Title: Management of large scale installations
Course Semester: 3rd
Country: France
Number of ECTS: 2

Aim: To have an insight on the management issues concerning the large scale facilities projects: from cost and security issues to inter-cultural collaborations, dissemination, etc.

Content:

The life circle of a large installation :
- Articulating needs, concept and studies
- Pre-project summary and detailed, construction and realization
- Integration, testing, qualification and reception, exploiting, operating and maintenance, upgrades, dismantling.
- transverse notions, security, safety, command control, risk management, quality assurance, reliability, certification, regulation duties (authorization and inspection files)
- industrialization and intellectual property, organization science.

Prerequisites: nothing specific

Recommended Books: nothing specific

Teaching Staff:
S. Meyroneinc (Institut Curie, Protontherapy center)

F. Matthieu (Apollon Laser Facility)

Grading System:
1/3 of the grade for written exam and 2/3 of the grade for a team project, no session 2

Hours: 30 hours in total
20 hours lectures
10 hours tuturial

COURSE SYLLABUS LASCALA master

Course Title: Practical on large scale facilities (8 days)
Course Semester: 3rd
Country: France
Number of ECTS: 4

Aim: to discover the every day life and work in a research laboratory at Paris Saclay close to large scale facilities

Content:

Practical work and numerical simulation work on research facilities of the Paris-Saclay Campus on the 3 following thematics :

- High Power lasers and Plasmas created by laser : Orsay/IJC Lab (Laserix), Palaiseau/LULI, Saclay/DMN, Saclay/IRAMIS, Palaiseau/LOA, Palaiseau/LCF
- Magnetic plasmas : Palaiseau/LPP (Torix)
- Particle accelerators : Palaiseau/LSI (Sirius), Orsay/IJC Lab, Saclay/IRFU, Bruyères/DPTA, SOLEIL, Institut Curie

Prerequisites: knowledge of experimental physics

Recommended Books: nothing specific

Teaching Staff:
S. Kazamias

Grading System:
each practical of 2 days corresponds to 1 ECTS, the grade over 20 is given by the hosting laboratory based on both practical work and written report

Hours :
Each practical 2 days in a laboratory
4 practicals in total

Course Title: Numerical methods
Course Semester: 3rd
Country: France
Number of ECTS: 3

Aim: This course is aimed at providing graduate level students with the required background for understanding computer science associated to the physics of hot plasmas and particle beams.

Content:

This course will address the interface between mathematics and physics, by showing the rules for transforming an analytical model based on derivatives, integrals and implicit equations understood by a theoretician into discretized, algebraic and explicit equations understood by computers. Hands-on session provide insight into physics complexity but they will be oriented onto the computer limits to catch such and such physics feature and onto the understanding and the control of the artefacts induced by the numerical model.

The course on computing about plasmas starts by displaying the reference quantities and the related orders of magnitude which characterize the plasmas, by listing the basic tools (matrix algebra, Fourier transform,…) associated to discrete values functions and by comparing the various models proposed to describe these plasmas and their validity limits. Then tools for analyzing an analytical model and to design consistent and stable numerical methods are provided. All the plasma models are then reviewed from the richest-slowest model to the poorest-fastest one:
o particle-in-cell methods to model the plasma kinetics of weakly coupled plasmas, where weakly damped collective effects are present ;
o finite difference methods for fluids models ;
o finite difference methods for wave-like models and their associated models, the envelope models.
o Stochastic methods
The lectures on stochastic simulation and modeling deal with the probabilistic elements needed for the design and implementation of stochastic algorithms. Are recalled and exposed the concepts of random variables, probability distributions, Markov chains, random processes and the results on stochastic differential equations. Physics equations of digital processing techniques are studied in detail and illustrated by computer simulations. After an introduction

to Monte-Carlo methods, the calculation of multidimensional integrals and Markovian processes, the course develops random techniques for the treatment of differential equations, in particular the Fokker-Planck equation, and the tools required for its resolution such as Brownian motion and stopping times. The rest of the course concerns: Feynman-Kac formulas, Probabilistic solution of a Dirichlet problem, Langevin equation, Ornstein-Uhlenbeck Processes, White and colored noise, Numerical schemes, Stochastic Korteweg de Vries Equation, Solitons, Smoluchowski equation as the limit of particulate systems, Transport equations, Fredholm equations and Boltzmann, Particle interactions.

Prerequisites: Basic knowledge (3rd year level) in classical thermodynamics and material science.

Recommended Books:

Numerical analysis

R.D. Richtmyer, K.W. Morton, *Difference methods for initial-value problems*, 2nd Edition, (Interscience Pub., New-York, 1967).

E.F. Toro, *Riemann solvers and numerical methods for fluid dynamics* (Springer, Berlin, 1997).

A. Iserles, *A First Course in the Numerical Analysis of Differential Equations* (Cambridge, 2004).

X.S. Yang, *Introduction to computational mathematics* (World Scientific, Singapour, 2008).

Plasma simulations

C.K. Birdsall, A.B. Langdon, *Plasma Physics via computer simulation*, (Mc-Graw-Hill, New York, 1985).

R.W. Hockney, J.W. Eastwood, *Computer simulation using particles* (Institute of Physics Publishing, Bristol, 1988).

T. Tajima, *Computational Plasma Physics: with applications to fusion and astrophysics* (Addison-Wesley, Redwood city, 1989).

Stochastic equations

S. Cyganowski, P. Kloeden, J. Ombach, *From Elementary Probability to Stochastic Differential Equations with Maple*, Springer, 2001.

Avner Friedman, *Stochastic Differential Equations And Applications*, Dover, 2006.

Simo Särkkä, Arno Solin, *Applied Stochastic Differential Equations*, CUP, 2019.

Bernt Oksendal, *Stochastic Differential Equations: An Introduction with Applications*, Springer, 2010.

C. Graham, D. Talay, *Stochastic Simulation and Monte Carlo Methods*, Springer, 2013.

P. E. Kloeden, E. Platen, *Numerical Solution of SDE*, Springer, 1992.

Teaching Staff:

Guy BONNAUD (CEA/DRF, Saclay, teaching laser-plasma interaction), Franck JEDRZEJEWSKI (CEA/INSTN, Saclay, teaching stochastic differential equations)

Grading System:

60 % written exam, 40 % homework partly exercices, partly simulation

Hours :

30 hours lecture + 15 hours homework