Advanced Topics In Physics I

2017-2018

This curricular unit is composed of several modules described below. Each student must choose a total of six modules and be evaluated in three iof them to complete this unit.
Timetables will be arranged after students choices are known. Modules take usually 5/6 weeks with 3/4 contact hours per week.

Modules

1. Experimental Particle and Astroparticle Physics (EXPAP), Antonio Onofre, U. Minho
2. Introduction to Composite Higgs Models (ICHM) , Nuno Castro and Mikael Chala
3. Data Analysis in Particle Physics (DAPP), Nuno Castro, U. Porto/U. Minho
4. High-Energy Physics Experiments (HEPX), José Ricardo Morais Silva Gonçalo. Sofia Andringa Dias.
5. Correlations Effects in Low-Dimensional Materials and Systems (CELDM), Jose Carmelo, U. Minho
6. Dark Energy, Dark Matter & Gravity (DEDMG), Orfeu Bertolami, U. Porto.
7. Lasers, optics and photonics (LOP), Mario Ferreira, U. Aveiro, [UNCONFIRMED]
8. Graphene plasmonics (GP), Yuli Bludov (U. Minho)
9. Advanced Materials Preparation and Characterization (AMPC), Bernardo Almeida, U Minho.
10. Nanomagnetism (NM), J E Araújo, U. Porto, Vitor Amaral, U. Aveiro.
11. Clean Room and Micro-fabrication (CRMF), Paulo Marques, João Oliveira Ventura, U. Porto
12. Group Theory and applications to Condensed Matter Phyiscs (GTACMP), Joaquim Agostinho Moreira, U. Porto
13. The Physics of Electronic Materials and Devices (PEMD), Pedro Alpuim,. U. Minho
14. Computational Physics (CP), Antonio Luis Ferreira, U. Aveiro, João Viana U. Porto.
15. Spectroscopic techniques for the characterization of materials (STCM), Luis Carlos, Rute André e N. Sobolev, and Luis Cadillon, U. Aveiro
16. Scanning Microscopy Techniques and Electronic Microscopy (SMT), Andrei Kholkine and Augusto Barros Lopes (U. Aveiro)

17. Biomedical Signal and Image Analysis (BSIA), Ana Paula Rocha, André Marçal, U. Porto
18. Biophotonics: sensing and imaging (BPSI) Carla Carmelo Rosa, J. Agostinho Moreira, U,. Porto
19. Nanomedicine: Science and Applications (NMSA) , André Trindade Pereira, U Porto.
20. Nuclear Medicine: SPECT, PET and radionuclides production (NMSPR), João Veloso, U. Aveiro
21. Numerical simulation of the atmosphere and ocean(NSAO), Alfredo Rocha, U. Aveiro
22. Climate variability and change (CVC), Alfredo Rocha, U. Aveiro
23. The Weather Research and Forecasting (WRF) model, Alfredo Rocha, U. Aveiro
24. Gauge/gravity duality (GGD) Daniel Arean (contact Miguel Costa)
25. Higher spin Theories (HST) Shailesh Lal (contact Miguel Costa)
26. Conformal Field Theory (CFT), Zhijin Li (contact Miguel Costa)
27. Communicating Science (CS), Ana Isabel Salgado, U. Minho
28. Energy Harvesting (EH) André Pereira, João Ventura U. Porto

Jury Panels

1. EXPAP: Antonio Onofre, Nuno Castro, Miguel Costa
2. ICHM: Nuno Castro, Mikael Chala and Juan Pedro Araque
3. DAPP: Nuno Castro, António Morais, João Veloso
4. HEPX: Antonio Onofre. José Ricardo Morais Silva Gonçalo. Sofia Andringa Dias,
5. CELDM: José Carmelo, João Lopes dos Santos, Antonio Luís Ferreira
6. DEDMG: Orfeu Bertolami, João Rosa, Filipe Mena
7. LOP: Mário Ferreira, Manuel Marques, Helder Crespo
8. GP: Nuno Peres, Yuliy Bludov, João Lopes dos Santos
9. AMPC: Bernardo Almeida, João Pedro Alpuim, Florinda Costa
10. NM: João Pedro Araújo, Vitor Amaral, João Ventura
11. CRMF: João Oliveira Ventura; Paulo Marques, Bernardo Almeida
12. GTACMP: Joaquim Agostinho Moreira, João Lopes dos Santos, José Carmelo
13. PEMD: Pedro Alpuim, Bernardo Almeida, Joaquim Leitão
14. CP: António Luís Ferreira, J V Lopes , Manuel Barroso
15. STCM: Luís Carlos, Luis Cadillon; Helder Crespo
16. SMT: Andrei Kholkine and Augusto Barros Lopes, João Ventura
17. BSIA: Ana Paula Rocha, André Marçal
18. BPSI: Carla Rosa, J. Agostinho, João Paulo Cunha
19. NMSA: André Miguel Trindade Pereira**,** Carla Rosa, Vitor Amaral
20. NMSPR: João Veloso, Carla Rosa, Joaquim Agostinho
21. `NSAO, Alfredo Rocha`
22. `CVC, Alfredo Rocha`
23. `WRF, Alfredo Rocha`
24. `GGD - Daniel Arean, Miguel Costa`
25. `HST, Shailesh Lal , Miguel Costa`
26. `CFT - Zhijin Li, Miguel Costa`
27. `CS : Ana Isabel Salgado`
28.

1. Curricular Unit

Advanced Physics Topics 1

Module

Experimental Particle and Astroparticle Physics , Advanced Analysis Methods, Top quark physics, Standard model and beyond (EXPAP)

Type

Lecture course

Contact hours

20 (12 T, 8 p)

Professor/Researcher in charge

Antonio Onofre,, U. Minho

Summary of Contents

This course involves the study of advanced analysis methods for PhD students within the field of Particle Physics. Following a theoretical revision on the current status of top quark physics, several applications are discussed. During the course, students are expected to be able to perform simple theoretical calculations related to top quark physics and explore the physics of its decay. The interplay between the top quark physics and the recently discovered Higgs boson is exercised as an application. Students are expected to analyse dedicated samples of ttH Monte Carlo events (with an hands-on approach). A production cross section limit at the LHC is extracted using advanced statistical tools.

Evaluation

Students are expected to follow at least 2/3 of the lectures, in both topologies i.e., Theoretical (T) and Theoretical-Pratical (TP). The grading plan involves attendance and participation in discussions, individual and team work as well as a final exam.
Coursework will be weighted as follows:

Attendance	10%
Individual/Team work	35%
Quizzes	25%
Final Exam	30%

Jury

Antonio Onofre, Nuno Castro, Miguel Costa

2. Curricular Unit

Advanced Physics Topics I

Module

Introduction to Composite Higgs Models

Type

Tutorial

Contact hours

18h

Professors/Researchers in charge

Nuno Castro and Mikael Chala

Summary of Contents

Composite Higgs models are one of the most appealing solutions to the Higgs hierarchy problem, to which both the theoretical and the experimental community are devoting important attention. The aim of this tutorial is introducing the basics of these models, with emphasis on explicit computations. The following topics will be covered:

- The Higgs hierarchy problem, origin and solutions.
- Dynamics of pseudo-Nambu-Goldstone bosons, the CCWZ formalism.
- The bosonic Lagrangian in the minimal model.
- The fermionic Lagrangian in the minimal model.
- Computation of the one-loop potential in the minimal model.
- Generic phenomenology of composite fermionic resonances.

Evaluation

The evaluation of the tutorial will be done in continuous way, with 5 exercises related to the content of the tutorial being proposed to the students. The final grade will be obtained by averaging the grades of exercices.Jury

Jury

Nuno Castro, Mikael Chala and Juan Pedro Araque

3. Curricular Unit

Advanced Physics Topics I

Module

Data Analysis in Particle Physics

Type

Tutorial

Contact hours

18h

Professors/Researchers in charge

Nuno Castro

Summary of Contents

The ability to fully explore the physics potential of the Large Hadron Collider (LHC) data relies on the ability to efficiently analyze the available dataset, maximizing the sensitivity to subtle signals hidden in a huge amount of background events. In the present tutorial will allow the students to acquire, in a supervised way, competences on advanced data analysis techniques, as well as expertise on some advanced tools commonly used in the high energy physics community.

During the tutorial, the following topics will be covered:

1) Monte Carlo Simulation
    1.1) Event generation and the use of Madgraph
2) Analysis tools
    2.1) Data analysis at the LHC
        2.1.1) Basic concepts
        2.1.2) C++ and ROOT
        2.1.3) Madanalysis
        2.1.4) Multivariate analysis techniques and the use of TMVA
3) Limit setting in searches for new physics phenomena

The tutorial will consist on a set of different exercises, designed to illustrate in an hands-on way, the use of the different tools and techniques, with the final goal being the development of a data analysis project by each student.

Evaluation

The evaluation will be done based on the discussions held during the contact hours, as well as on the final project, according to the following weights:

Discussions during the contact hours: 10%

Quality of the developed project: 50%

Defense and presentation of the developed project: 40%

Jury

Nuno Castro, António Morais, João Veloso

4. Curricular Unit

Advanced Physics Topics I .

Module

High-Energy Physics Experiments (HEPX)

Type

Lecture Course

Contact hours

18h

Professors/Researchers in charge

José Ricardo Morais Silva Gonçalo. Sofia Andringa Dias

4. Summary

The exploration of the Standard Model of particle physics, and of what lies beyond it, relies on hugely complex, state of the art experiments, which push the boundaries of several types of technology. This course gives an overview of the main contemporary particle physics experiments, focusing on the technologies which enable us to probe Nature at the most fundamental level, providing students in experimental or theoretical particle physics with the background knowledge to better understand data emerging from these experiments.

5. Contents

The detailed programme will contain the following topics:

1. Review of modes of interaction of radiation in matter
2. Review of main types of radiation detectors: gas-based, semiconductor, scintillating, Cherenkov, calorimeters
3. Accelerator physics
4. Examples of contemporary particle physics experiments

a. Collider experiments (e.g. ATLAS, etc)

b. Low-counting/high-purity experiments (e.g. LZ)

c. Cosmic-ray experiments (e.g. Auger)

5. Trigger systems
6. Event reconstruction

a. Electron, photon, muon and tau-lepton reconstruction

b. Hadronic jet reconstruction and jet physics

Evaluation

Students are expected to follow at least 2/3 of the theory and practical sessions.

The final classification will be a weighted average of the following factors: attendance and participation in class (20%), development of the project in the practical sessions (30%), presentation of the project (50%).

Bibliography

William R. Leo, Techniques for Nuclear and Particle Physics Experiments - A How-to Approach, Springer Verlag

Klaus Wille, The Physics of Particle Accelerators – an Introduction, Oxford University Press

Glen Cowan, Statistical Data Analysis, Oxford University Press.

Jury

José Ricardo Morais Silva Gonçalo. Sofia Andringa Dias, Antonio Onofre

5. Curricular Unit

Advanced Physics Topics 1

Module

Correlations Effects in Low-Dimensional Materials and Systems (CELDM)

Type

Tutorial

Contact hours

18

Professor/Researcher in charge

José Carmelo, U. Minho

Summary of Contents

Why are the effects of many-body interactions more important in lower dimensions?
The Fermi liquid versus non-perturbative low-dimensional electronic problems.
The Luttinger liquid and beyond it.
Solvable 1D electronic models.
Different properties of integrable and non-integrable 1D quantum problems.

Evaluation

Written report with oral defense

Jury

José Carmelo, João Lopes dos Santos, Antonio Luís Ferreira

6. Curricular Unit

Advanced Physics Topics 1

Module

Dark Energy, Dark Matter & Gravity (DEDMG)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

Orfeu Bertolami

Summary of Contents

Recent observational evidence arising from the cosmic microwave background radiation (CMB), from type Ia supernovae (SNe-Ia), from baryon acoustic oscillations (BAO), etc, indicate that the expansion of the Universe is accelerating, and that matter that can be observed through the electromagnetic radiation cannot account for the formation of galaxies, cluster and superclusters of galaxies. These observations suggest that, on large scales, the dynamics of the Universe is dominated by a smooth uniformly distributed form of energy, dark energy, and that structure formation requires a substantial amount of a new form of matter, dark matter. The nature and the characterization of these dark components are central issues in contemporary cosmology. Of course, a relevant related question is whether the observations can be accounted by alternative theories of gravity. Thus, in these lectures, observational and theoretical ideas and proposals to unravel these open questions will be discussed.

References

Dynamics of dark energy , E. Copeland, M. Sami, S. Tsujikawa. Mar 2006 - 84 pages Int.J.Mod.Phys. D15 (2006) 1753-1936 DOI: 10.1142/S021827180600942X , e-Print: hep-th/0603057
Astrophysical and cosmological probes of dark matter, M. Roos. Aug 2012. 39 pp. e-Print: arXiv:1208.3662 [astro-ph.CO]
Dark Matter: The evidence from astronomy, astrophysics and cosmology Matts Roos. Jan 2010. 25 pp. e-Print: arXiv:1001.0316 [astro-ph.CO]

Jury

Orfeu Bertolami, João Rosa, Filipe Mena

7. Curricular Unit

Advanced Physics Topics 1

Module

Lasers, optics and photonics (LOP)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

Mario Ferreira, U. Aveiro

Summary of Contents

This module will cover several topics that illustrate the revolution in optical area during the last decades, following the invention of the LASER. Special attention will be paid to some latest developments within optical communications and nonlinear optics.

Evaluation

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Jury

Mário Ferreira, Manuel Marques, Helder Crespo

8. Curricular Unit

Advanced Physics Topics 1

Module

Graphene plasmonics (GP)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

Yuliy Bludov

Summary of Contents

This module exposes the students to basic concepts of the rapidly emerging area of graphene plasmonics. The practical interest of this area is determined by the small wavelength of the surface polaritons, when compared to that of bulk electromagnetic waves, which allows the miniaturization of photonic components. Furthermore, this gives rise to a higher localization of the surface polaritons, which are characterized by lower damping, in comparison with noble metals. The possibility to dynamically tune graphene's conductivity through the variation of a gate voltage introduces and extra degree of freedom into the problem. In this module students contact with basic knowledge on the optical properties of graphene and on the properties of surface polaritons (a special kind of electromagnetic waves, propagating along surfaces and interfaces) both in noble metals and in graphene (a 2D carbon material). The theory of surface polaritons in graphene, dispersion relations and methods for exciting these type of waves, is explained. Finally the description of experimental works as well as the corresponding operational principles will be detailed. Detailed program:
1.) electronic properties of graphene and its optical conductivity;
2.) Drude model for metals and for graphene;
3.) Surface plasmon-polaritons in noble metals;
4.) Surface plasmon-polaritons in graphene;
4.) Methods for exciting surface plasmon-polaritons;
5.) Some experiments using the excitation of surface plasmon-polaritons;
6.) Localized plasmons in graphene based nano-structures.

Evaluation

1.) For new comers to the subject: One written report and one introductory computational project.

2.) For experts on the topic: One research project, which must be presented in the end of the semester in front of the class.

Note: Any student can opt for one or the other type of evaluation

Jury

Nuno Peres, Yuliy Bludov, João Lopes do Santos

9. Curricular Unit

Advanced Physics Topics 1

Module

Advanced materials preparation and characterization (AMPC)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

Bernardo Almeida, U. Minho

Summary of Contents

Thin film preparation. Sputtering. Magnetron sputtering. Applications.
Laser Ablation deposition of thin films and nanostructures. Applications.
Structure and microstructure. X-ray diffraction. Low angle X-ray scattering, reflectometry, grazing incidence. Scanning electron microscopy (SEM). Transmission electron microscopy (TEM)
Infrared and Raman Spectroscopies. Lattice dynamics. Experimental setups. Applications.
Electrical properties. Dielectric relaxation. Impedance spectroscopy. Time and frequency domains. Experimental setups. Electrical resistivity. Magnetoresistance.
Magnetic properties. Magnetic interactions and magnetization. Magnetometry. Measurement techniques.
Optical properties. Reflectance and transmittance. Absorption. Photoluminescence. Ellipsometry.

Evaluation

Final exam

Jury

Bernardo Almeida, João Ventura, Florinda Costa

10. Curricular Unit

Advanced Physics Topics 1

Module

Nanomagnetism (NM)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

João Pedro Araújo, U. Porto, Vitor Amaral (U. Aveiro)

Summary of Contents

Magnetism: basic macroscopic concepts. Magnetic moment, diamagnetism, paramagnetism. Macroscopic description: field and temperature dependence of a spin ½ paramagnetic system.

Spin, orbital and magnetic momentum. Electronic configurations, Hund rules, 3d and 4f atoms/ions

Brillouin function, Curie law, Pauli paramagnetism. Perturbation theory and Van Vleck paramagnetism. Magnetic interactions, microscopic description, ferromagnetism, ferrimagnetism, antiferromagnetism. Electronic correlations. Mean field models. Curie-Weiss law

The Landau theory of phase transitions: order parameters, equation of state, critical temperature and exponents, Arrott-Belov plots, coupled magneto-volume phase transitions, the magnetocaloric effect.

The Bean-Rodbell model, scaling plots, critical phenomena, the Ising and Heisenberg models, the Arrott-Noakes equation of state.

Magnetic domains. Magnetostatic energy, anisotropy energy. Domain walls.

Magnetic nanoparticles, Stoner-Wolfhart model.

Superparamagnetism, relaxation, Néel and Brown mechanisms. Energy distributions, dipolar interactions, surface effects. Exchange bias. Applications: recording, hyperthermia and magnetic resonance imaging.

Evaluation

Written essay on selected topics. Oral presentation (15') followed by discussion (10').

Jury

João Pedro Araújo, Vitor Amaral, João Ventura

11. Curricular Unit

Advanced Physics Topics 1

Module

Clean Room and Micro-fabrication (CRMF)

Type

Practical instruction

Contact hours

18

Professor/Researcher in charge

Paulo Vicente Marques

Summary of Contents

This course will introduce, in a hands-on approach, the main microfabrication and deposition techniques used to produce functional devices in a Clean Room environment. Basic training in the use of a Clean Room, including basic facility description, operating procedures and safety instructions, will be provided. Ion beam deposition, resistive and electron-beam evaporation will be used to grow metallic and insulating thin films. The resolution and minimum feature size attainable by optical lithography will be studied using Direct Write Laser and Mask Alignment systems. Pattern transfer techniques (dry and wet etching and lift-off) will allow the comparison of their selectivity, anisotropy and etching rate. Basic characterization of the produced structures will be performed using optical microscopy and perfilometry, to extract relevant parameters (thin film roughness, thickness, deposition rates and uniformity; feature sizes, distributions, etching profiles). This module will take place in the recently installed Clean Room of the Porto University, CEMUP MNTEC.

Evaluation

Essay and oral presentation

Jury

João Oliveira Ventura; Paulo Marques, Bernardo Almeida

12. Curricular Unit

Advanced Physics Topics 1

Module

Group Theory and Applications to Condensed Matter Physics

Type

Tutorial: Reading and Study assignment

Contact hours

18

Professor/Researcher in charge

Joaquim Agostinho Moreira , U. Porto

Summary of Contents

Representations theory and basic theorems. Character of a representation and basis functions.
Direct product and its representations. Application to selection rules and splitting of atomic levels in a crystal field.
Space groups in real space and in the reciprocal space. Symmetry of the k vectors and the group of the wave vector. Representations of a space group. Little group and stars. Factor group analysis and the Γ point. Points for k≠0. Compatibility relations.
Applications to lattice vibrations and electronic energy levels. Energy band models based on symmetry. Spin-orbit coupling in solids and double groups and application to energy bands with spin.
Time reversal symmetry. The Magnetic Groups and their Corepresentations. Properties of the magnetic point groups.

References

Group Theory. M. S. Dresselhaus, G. Dresselhaus, and A. Jorio. Springer. 2008
The Mathematical Theory of Symmetry in Solids. Representation Theory for Point Groups and Space Groups. C. Bradley and A. Cracknell. Oxford Classic Texts in the Physical Sciences. 2010.
J. L. Ribeiro. Phys. Rev. B 76, 144417 (2007).
J. L. Ribeiro and L. G. Vieira. Phys. Rev. B 82, 064410 (2010)
I. Urcelay-Olabarria, J. M. Perez-Mato, J. L. Ribeiro, J. L. García-Muñoz, E. Ressouche, V. Skumryev, and A. A. Mukhin. Phys. Rev. B 87, 014419 (2013).

Jury

Joaquim Agostinho Moreira, João Lopes dos Santos, José Carmelo

13. Curricular Unit

Advanced Physics Topics 1

Module

The Physics of Electronic Materials and Devices (PEMD)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

João Pedro Alpuim; palpuim@fisica.uminho.pt

Summary of Contents

Continued miniaturization of silicon devices paved the way for a host of electronic appliances that revolutionized our day-to-day life during the last half century. Nanotechnology is currently introducing a new level of complexity into very small objects that in turn will allow this dizzying pace of miniaturization not only to keep up but possibly to accelerate.
This module is designed to provide a broad view of electronic materials and devices and their fabrication techniques, going from the well-established Si-based technology, through magnetic devices for data storage, up to sensors based on new 2D materials and their applications. The module includes a session hosted by INL in Braga, where students will be introduced to the state-of-the-art facilities that are available at the institute.

Electrons in solids (5 hours)
Electrons in a periodic field of a crystal
Energy bands in metal and semiconductor crystalline solids
Band structures in 3D, 2D and 1D
Electrons in nanostructures: Landauer resistance, Coulomb blockade and resonant tunneling

Micro/nanoelectronic semiconductor devices (5 hours)
The p-n junction and the bipolar transistor
The LED and the LASER
The field-effect transistor: NMOS, CMOS and 2D materials FETs

Macroelectronic devices (2 hours)
Solar cells
MEMS and NEMS devices
Displays

Sensors and data storage (3 hours)
Biosensors
Magnetic devices
Top down fabrication of micro and nanostructures (3 hours)

Bibliography:

Solid State Physics, N. W. Ashcroft, N. D. Mermin, Saunders College Publishing. Harcourt College Publishers. Fort Worth Philadelphia (1976).

Physics of Semiconductor Devices, S.M. Sze, K.K. Ng, J. Wiley & Sons Inc., New York, 3rd Edition (2006).

Introduction to Nanoelectronics, by V.V. Mitin, V.A. Kochelap and M.A. Stroscio, Cambridge University Press, Cambridge (2008).

Introduction to Nanoscience, S.M. Lindsay, Oxford University Press, Oxford (2010).

Fundamentals of microfabrication: the science of miniaturization, Marc J. Madou, Taylor & Francis, Inc., 2nd Edition, New York (2002).

Evaluation

Student grading will be based on a final individual exam containing conceptual questions and problems to be solved by the student. Grading will be based on a 0-20 scale and to get approval the student must obtain at least grade 10.

Students can also adhere voluntarily to a scheme of periodic evaluation of their work, based on the weekly resolution of a problem chosen by the professor and to be returned the following class. Students can seek information of any sort in order to solve the proposed problem but they compromise to do it individually. In every class, 20 minutes of lecture time will be devoted to the discussion of the solution of that week's problem and the methods used to obtain it. Any of the students having returned the problem solved in a particular week can be asked by the professor to introduce that discussion orally, based on the solution and the way he/she obtained it. In case he or she fails to do so, the problem will not be considered for evaluation. There will be a series of 8 weekly problems, each valued 2.5 points, and totalizing 20 points. Each student can enter/leave this evaluation program freely. The student will be approved in this scheme when he/she accumulates at least 10 points. In this case he/she can decide not to present himself/herself to the final exam in which case his/her final grade will be the sum of the points accumulated in the periodic evaluation of his/her work.

Jury

Pedro Alpuim, Bernardo Almeida, Joaquim Leitão

14. Curricular Unit

Advanced Physics Topics 1

Module

Computational Physics (CP)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

Antonio Luis Ferreira, U. Aveiro, J Viana Lopes , U. Porto

Summary of Contents

Part 1 (9 hours) Monte Carlo Methods in Statistical Physics. Markov Chains: Chapman-Kolmogorov equation; Transient and stationary regimes; Detailed balance.
Monte-Carlo Integration: Hit or Miss Monte-Carlo; integration as an average calculation; random Sampling; importance sampling; Markov Chain Monte-Carlo; Metropolis algorithm
Applications to Statistical Physics: ergodicity; detailed balance; equilibration; estimating errors.
Part 2: Introduction to the Kernel Polynomial Method for disordered electronic
Application to Physical Problems (typical Hamiltonians, observables). Numerical implementation. Parallelization.

References

Understanding Molecular Simulations, Daan Frenkel and Berend Smit
Computer Simulation of Liquids, M P Allen and D J Tildesley
Monte Carlo Methods in Statistical Physics, by Mark Newman, G T Barkema
Parallel Programming in C with MPI and OpenMP", Michel J. Quinn, 2004, McGraw-Hill.
Parallel Programming with MPI, Peter S. Pacheco, 1997, Morgan Kaufmann.
The Kernel Polynomial method., Alexander Weiβe, et al. Rev. Mod. Phys,. **78**, 275, 2006

Evaluation

Exam with computational exercises (part1); written report with oral defense (part2).

Jury

António Luís Ferreira, J V Lopes , Manuel Barroso

15. Curricular Unit

Advanced Physics Topics 1

Module

Spectroscopic techniques for the characterization of materials (STCM)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

Luis Carlos, U. Aveiro

Summary of Contents

Optical properties;
Photoluminescence in steady state and time resolved (emission spectra and emission decay curves) modes.
Quantification of the emission features (Absolute quantum yield, photometric and radiometric parameters, colour coordinates)
Ellipsometry. Fundamentals and applications. Structural modelling.
Electric properties; EPR

Evaluation

Written Test (3h).

Jury

Luís Carlos, Florinda Costa; João Pedro Araújo

16. Curricular Unit

Advanced Physics Topics 1

Module

Scanning Microscopy Techniques (SMT) and Electronic Microscopy (MGTEM)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

Andrei Kholkine and Augusto Barros Lopes (U. Aveiro)

Summary of Contents

This module is designed to provide a broad view of the principles and fundamentals of different microscopy techniques, namely scanning microscopy and electron microscopy.

Scanning microscopy
Survey of STM and SPM methods and their comparison with other microscopic techniques
STM and AFM instrumentation
Scanning Tunnelling Microscopy and applications
Forces at the nanoscale and contact AFM
Contact vs. non-contact and tapping AFM.
Electrostatic and Magnetic Force Microscopy
Kelvin Force Probe Microscopy
Piezoresponse Force Microscopy and nanoscale characterization of ferroelectrics.
Scanning Near-field Optical Microscopy
Nanoindentation
Scanning Spreading Resistance Microscopy
AFM demonstration and practical classes

2. Electronic microscopy

The electron microscopy as a materials characterization technique

The depth of field and the resolution limit of the optical microscope

Advantages of using electrons

The basic constitution and working principles of the scanning electron microscope (SEM), the

transmission electron microscope (TEM) and the scanning transmission electron microscope (STEM).

Sample preparation for SEM and TEM

The Energy Dispersive Spectroscopy (EDS).

SEM and EDS practical demonstration

The interaction volume. Influence of the atomic number, thickness, electron beam energy and sample tilting.

SEM observation modes. Secondary and backscattered electron image modes.

TEM Image and diffraction modes

TEM Contrast. Mass-Thickness contrast, diffraction contrast (bright and dark field image modes) and phase contrast

TEM practical demonstration

Evaluation

Written essay on selected topics. Oral presentation (15') followed by discussion (10').

Jury

Andrei Kholkine and Augusto Barros Lopes, João Ventura

17. Curricular Unit

Advanced Physics Topics 1

Module

Biomedical Signal and Image Analysis

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

Ana Paula Rocha, André Marçal

Summary of Contents

Digital and Statistical Signal Processing review. Biomedical Signal Processing: Short introduction. Selected advanced analysis tools of current modern biomedical signal processing and application, such as: time-frequency, time-scale and wavelet analysis; optimal, adaptive and Kernel methods; complexity/ nonlinear dynamics modeling; PCA/ICA multivariate analysis.
Image Processing fundamentals. Image Segmentation, classification and annotation. The Radon Transform and image reconstruction.

Bibliography

Semmlow,J.L., Griffel,B. 2014, Biosignal and Medical Image Processing, CRC Press, ISBN 978-1-4665-6737-5
K.L. Blinovska and J Zygierewicz,Pratical Biomedical Signal Analysis using Matlab, Series in Medical Physics and Biomedical Engineering, CRC Press 2012
S. Cerutti, C. Marchesi eds., Advanced Methods of Biomedical Signal Processing, IEEE Wiley, 2011.
Gonzalez, R.C., Woods, R.E., 2008, Digital Image Processing, Addison-Wesley, ISBN: 978-0-13-168728-8
C.L.Epstein, 2008, Introduction to the Mathematics of Medical Imaging, 2nd Edition, SIAM, ISBN 978-0-89871-642-9

Evaluation

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Jury

Ana Paula Rocha, André Marçal

18. Curricular Unit

Advanced Physics Topics 1

Module

Biophotonics: sensing and imaging

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

Carla Carmelo Rosa, J. Agostinho Moreira

Summary of Contents

- Optical properties of biological tissues, and the physics of light-tissue interactions
- Characterization of bio-tissues: advanced optical imaging and light spectroscopy techniques
- Light induced modifications of bio-tissues: clinical applications of lasers, and safety.
- Vibrational spectroscopies: principles and applications. Instrumentation.
- Biophysical applications of the micro-Raman spectroscopy. Biological vibrational imaging.
- Surface-enhanced Raman spectroscopy (SERS): electromagnetic theory and Mie theory. Instrumentation. Single-molecule SERS. Nanosensors based on SERS.
- SERS for biomedical diagnostics and molecular imaging.

Bibliography

1. *Markolf H. Niemz; Laser-tissue interactions. ISBN: 978-3-540-72191-8, 2007.*
2. *R. Splinter; An introduction to biomedical optics. ISBN: 0-7503-0938-5, 2007.*
3. *Lihong V. Wang; Biomedical optics. ISBN: 978-0-471-74304-0, 2007.*
4. *Barry R. Masters; Confocal microscopy and multiphoton excitation microscopy. ISBN: 978-0-8194-6118-6, 2006.*
5. *Hans-Ulrich and Bing Yan (Eds). Infrared and Raman Spectroscopy of Biological Materials. Practical Spectroscopy Series. ISBN 0-8247-0409-6, 2001.*
6. *Katrin Kneipp, martin Moskovits and Harald Kneipp. Surface-Enhanced Raman Scattering, Physics and Applications. ISBN: 978-3-540-33566-5, 2006.*
7. *Influence of substrate temperature on the properties of pulsed laser deposited silver nanoparticle thin films and their application in SERS detection of bovine serum albumin. Koppole Kamakshi, J. P. B. Silva, K. C. Sekhar, Gregory Marslin, J. Agostinho Moreira, O. Conde, A. Almeida, M. Pereira, M. J. M. Gomes. Appl. Phys. B 122,108 (2016).Team, M. C.*

(2003).

8. *Surface plasmon resonance coupled photoluminescence and resistive switching behavior of pulsed laser deposited Ag:SiC nanocermet thin films. Koppole Kamakshi, K C Sekhar, A Almeida, J Agostinho Moreira, M J M Gomes. Plasmonics. DOI 10.1007/s11468-015-9915-4 (2015).*

Evaluation

[To be defined]

Jury

Carla Rosa, J. Agostinho, João Paulo Cunha

19. Curricular Unit

Advanced Physics Topics 1

Module

Nanomedicine: Science and Applications

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

André Miguel Trindade Pereira

Summary of Contents

This course provides a thorough overview and a state-of-the-art of the exciting and emerging field of Nanomedicine which has already transformed the way that medical and healthcare solutions are developed and delivered.

The course has the following contents:

Introduction to Nanomedicine

This section will be focused on the introduction to Nanotechnology for Medicine and Healthcare. The basic concepts on nanomaterials in Medicine and the nanoscale relation to biological systems (cell, virus, blood) will be discussed. Toxicology and safety of nanomaterials will be presented since they are essential aspects when working in biomedical applications. Finally, innate and adaptive immune responses of biological systems to nanomaterials will end the first section.

Nano-Diagnostics

This section will be focused on the main applications of nanoparticles to the Nanomedicine field. An overview to nano-diagnostics will be provided, followed by the application of microvesicles and nanovesicles in health and disease. The engineered nanoparticles will be afterwards presented for:

i) Medical imaging (ultrasound, optical, computed tomography, magnetic resonance imaging and positron emission tomography);

ii) Cancer diagnostics: *In vitro* & *In vivo* diagnostics.

At the end, DNA sequencing and DNA microarrays for medical diagnostics will be presented.

Nanotechnologies for regenerative medicine and tissue engineering

In this section will be discussed Nanomaterials for regeneration of bone and cartilage as well as scaffolding and nanocomposites for tissue engineering. Electrospinning in tissue engineering and nanomaterials in dentistry will be presented at the end of this section.

Nano-Biosensors

This section will be devoted to the main requirements of biosensing systems, being afterwards focused on electrochemical sensing and optical sensing methodologies. Nano-biosensors (devices) and the main challenges to validate biosensors in the clinical setting will be presented.

Nano-Pharmaceuticals

This section will be focused on nanotechnologies and nanoparticles for drug delivery and therapy, on *in vivo* location and biodistribution of nanoparticle. Nanoparticle targeting, bio-nanotherapeutics and nanopharmaceuticals will be discussed. A special focus on magnetic hyperthermia will be provided.
Finally, the new trend on Theranostics, combining medical diagnosis with therapy, will be the last topic addressed in this section.

Trends, challenges and opportunities in Nanomedicine

In this section important aspects of Nanomedicine will be discussed such as, ethics, regulation approval in Nanomedicine and industrial perspectives. Finally, the market analysis, future trends and opportunities will be addressed.

Bibliography

[1] P.N. Prasad, “Introduction to Nanomedicine and Nanobioengineering”, John Wiley & Sons Inc. (2012).
[2] R. Bawa, G.F. Audette, I. Rubinstein, “Handbook of Clinical Nanomedicine: Nanoparticles, Imaging, Therapy, and Clinical Applications”, CRC press, Taylor & Francis Group (2016).
[2] A.M. Pereira, C. Pereira, A.S. Silva, D.S. Schmool, C. Freire, J.-M. Greneche, J.P. Araujo, “Unravelling the effect of interparticle interactions and surface spin canting in gamma-Fe_2O_3@SiO_2 superparamagnetic nanoparticles”, Journal of Applied Physics, 109 (2011) 114319.

[3] C. Pereira, A.M. Pereira, M. Rocha, C. Freire, C.F.G.C. Geraldes, “Architectured design of superparamagnetic Fe_3O_4 nanoparticles for application as MRI contrast agents: mastering size and magnetism for enhanced relaxivity”, Journal of Materials Chemistry B, 3 (2015) 6261–6273.

Evaluation

[to be defined]

Jury

André Miguel Trindade Pereira**,** Carla Rosa, Vitor Amaral

20. Curricular Unit

Advanced Physics Topics 1

Module

Nuclear Medicine: SPECT, PET and radionuclides production

Type

Lecture

Contact hours

18

Professor/Researcher in charge

João Veloso (U . Aveiro)

Summary of Contents

Address the thematics associated with Nuclear Imaging, focusing on the physics and the related state-of-the-art techniques and instrumentation and radionuclides production. Depending of the students background, an introduction of the physical aspects associated with the interaction of ionizing radiation with matter, will be done

Bibliography

J Bushberg et al, *The Essential physics of Medical Imaging*, *third edition*, Lippincott Williams & Wilkins, 2012.
W R Hendee, E R Ritenour, *Medical Imaging Physics*, *Wiley*
recent publications from journals related with the thematics of the course.

Evaluation

[To be defined]

Jury

João Veloso, Carla Rosa, Joaquim Agostinho

21. Curricular Unit

Advanced Physics Topics I

Module

`Numerical simulation of the atmosphere and ocean`

Type

tutorial

Contact hours

18h

Professors/Researchers in charge

Alfredo Rocha

Summary of Contents

History of numerical modelling in atmospheric/oceanic sciences

Conservation equations

Methods to solve the equations

Vertical coordinates

Initial conditions

Data assimilation

Boundary conditions

Ensemble forecasting

Physical parametrizations

Evaluation

Written report

Jury

Alfredo Rocha

22. Curricular Unit

Advanced Physics Topics I

Module

`Climate variability and change`

Type

tutorial

Contact hours

18h

Professors/Researchers in charge

Alfredo Rocha

Summary of Contents

State-of-the-art numerical models of the climate system.
The climate system: Interaction amongst climate sub-systems; feedbacks in the climate system.
Forcing agents of climate.
Climate variability and change simulations due to external forcing

Evaluation

Written report

Jury

Alfredo Rocha

23 Curricular Unit

Advanced Physics Topics I

Module

`The Weather Research and Forecasting (WRF) model`

Type

tutorial

Contact hours

18h

Professors/Researchers in charge

Alfredo Rocha

Summary of Contents

The WRF model development.

Data assimilation.

Physics parametrization development and testing.

Regional climate simulations with WRF.

Model evaluation.

Evaluation

Written report

Jury

Alfredo Rocha

24. Curricular Unit

Advanced Physics Topics I

Module

Gauge/gravity duality

Type

`Lecture/tutorial`

Contact hours

18h

Professors/Researchers in charge

Daniel Arean

Summary of Contents

[TO be defined]

Evaluation

To be defined

Jury

Daniel Arean, Miguel Costa

25. Curricular Unit

Advanced Physics Topics I

Module

Higher spin Theories

Type

`Lecture/tutorial`

Contact hours

18h

Professors/Researchers in charge

Shailesh Lal

Summary of Contents

[TO be defined]

Evaluation

To be defined

Jury

Shailesh Lal, Miguel Costa

26. Curricular Unit

Advanced Physics Topics I

Module

Conformal Field Theory

Type

`Lecture/tutorial`

Contact hours

18h

Professors/Researchers in charge

Zhijin Li

Summary of Contents

[TO be defined]

Evaluation

To be defined

Jury

Zhijin Li Miguel Costa

27. Curricular Unit

Advanced Physics Topics I

Module

Communicating Science

Type

Lecture Course

Contact hours

18h

Professors/Researchers in charge

Ana Isabel Salgado

Summary of Contents

By the end of this course students will be able to:

Demonstrate the ability to reflect critically about the impact of communication in interpersonal relationships (potentialialities and constraints of communication);

Identify and apply the necessary tools (knowledge, attitudes and behaviors) that support the development of public speaking skills;

Communicate effectively in an oral presentation;

Formulate a well-organized argument supported by evidence, strengthening the researcher's role in the scientific community and in the society in general;

Achieve higher rates of satisfaction and lower levels of anxiety associated with public speaking.

Contents

Communicating Science;

Target your talk;

Organize your presentation;

Visual aids;

Voice and language;

Body language and gestures;

Take control of the situation;

When the unexpected happens;

Handling question and answer sessions;

Inspire your audience.

Evaluation

Active participation in training sessions (minimum passing requirement: 75% total hours)
Individual talk (minimum passing grade: 9,5): comment with a reflexive/critical analysis and a theoretical foundation
Final grade = 0,4 active participation + 0,6 individual talk

Jury

Ana Isabel Salgado

28.Curricular Unit

Advanced Physics Topics I

Module

New Trends of Energy Harvesting towards innovative and efficient Nanogenerators

Type

Lecture Course

Contact hours

18h

Professors/Researchers in charge

André Miguel Trindade Pereira/João Oliveira Ventura

Summary of Contents

Internet-of-Things (IoT) has become a growing concept with a potential to affect how we live and how we communicate with the “Livings” and the “Things” around us. IoT is a concept of connecting all the daily use devices into the internet such as mobile phones, refrigerator, computers, doors, gadgets, and cars. Although this is an emerging area, there has been an increase in activities to find solutions for extending the lifetime operation for wearables. Energy harvesting is an emerging topic that can be utilized to recharge/replace batteries in low power application. Although, energy harvesting has been known for decades, however, it is becoming possible to harvest since the power consumption of electronic circuits has become low enough to be powered by energy harvesting sources. Further, recent researches in circuit design have pushed the power consumption of electronic circuit as low as possible. In addition, state-of-the-art harvesters have become small, efficient, flexible which allow these harvesters to be integrated into small form factor. This will be the main topic of the present course.

The course has the following contents:

Introduction to Energy Harvesting
NanoPiezoeletric Generators
NanoTriboelectric Generators
NanoThermoelectric Generators
RF Harvesting
Fuel Cells
Hybridization of energy harvesters
Trends, challenges and opportunities in Energy Harvesting

Bibliography:

[1] Mohammad Alhawari Baker Mohammad Hani Saleh Mohammed Ismail “Energy Harvesting forSelf-Powered Wearable Devices” Springer 2017. [2] Cátia R.S. Rodrigues, Carla A.S. Alves, Joel Puga, André M. Pereira, João O. Ventura “Triboelectric driven turbine to generate

electricity from the motion of water" NanoEnergy **30** 379-386 (2017)

Evaluation

Written essay on selected topics. Oral presentation (15') followed by discussion (10')

Jury

André Miguel Trindade Pereira, João Oliveira Ventura