PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

HARMONIZATION

MASTER TRAINING OFFER

ACADEMIC

Etablissement	Faculty	Département
Djilali Bounaama Khemis Miliana University	Science and Technology Material Sciences	Material Sciences

Domain: Physical sciences

Field: Physics

Speciality: Theoretical physics

Academic year : 2015- 2016

الجمهورية الجزائرية الديمقراطية الشعبية

وزارة التعليم العالي والبحث العلمي

مواءمة

عرض تكوين ماستر

أكاديمي / مهني

القسم	الكلية/ المعهد	المؤسسة
علوم المادة	كلية العلوم والتكنولوجيا	جامعة خميس مليانة

الميدان : علوم المادة

الشعبة : الفيزياء

التخصص : الفيزياء النظرية

السنة الجامعية: **2016-2015**

SOMMAIRE

I – Identity card of the Master

1 - Training location:

Faculty (or Institute): faculty of science and technology

Department: Material sciences

2- Training partners:

- Other university establishments:

- Companies and other socio-economic partners:

- International partners :

3 –Context and objectives of the training

A – Access conditions (*indicate the license specialties that can give access to the Master)*

- Fundamental Physics License.
- Theoretical Physics License.
- Bachelor's degree in Radiation physics.
- Other licenses and Physics DES (access after study of the files).

B - Training objectives *(*skills targeted, pedagogical knowledge acquired at the end of the training - maximum 20 lines)

This master offers a high-level training in fundamental physics, in particular theoretical physics. This leads to both teaching and research. It covers a wide range of physics fields ranging from low energies like condensed matter physics to high energies like elementary particle physics. It deals with particle physics, mathematical physics, quantum mechanics and many other specialties.
Theoretical education provides in-depth training in physics and a solid introduction to research, which will allow him to integrate a university or research laboratory without any problem.

C –Targeted business profiles and skills

- Train qualified researchers in physics, especially in theoretical physics.
- Train physics teachers for the education sector

D- Regional and national employability potential of graduates

- National Ministry of Education;
- Ministry of Higher Education and Scientific Research;
- Research Centers other than those under the MESRS.
- Research Laboratories.

E – Bridges to other specialties

There are several pathways, particularly to the specialties listed below:
- Nuclear physics.
- Statistical physics.

F –Training monitoring indicators

- Meetings of the Pedagogical Coordination Committee.
- In addition to these meetings and tutorials, teaching is conducted in the form of tutoring is offered to students, giving rise to contact with teacher-researchers around certain topics of the course to inquire about problems encountered by students.
- The number of students graduating from this training continuing their studies in Doctorate.
- Success rate and number of dropouts during the training.
- Hiring rate of students from this training.
- Training deficiencies reported by outgoing students.

G – Supervision capacity (give the number of students that can be supported)

- 20 students.

4 - Available human resources

A: Teachers of the establishment intervening in the specialty:

Nom, prénom	Diplôme graduation + Spécialité	Diplôme Post graduation + Spécialité	Grade	Type d'intervention *	Emargement
Ouardane Abdellah	DES. PHYS. Solide	Habilitation Phys	MCA	Encadrement	
Diaf Ahmed	DES PHYS. Rayonnement	Habilitation	MCA	C+Encadrement	
Boukabcha Houcine	DES : Physique des Rayonnements	Docteur en physique théorique	MCB	C.TD.TP.Encad_	
Bentridi Salah Edine	D.E.S phys. Ray.	Docteur en phys. théorique	MCB	Encadrement	
Douici Mohamed	D.E.S Physique les Rayonnements,	Docteur en Physique Théorique	MCB	C.TD.Encad_	
Chaouichi Belkacem	Lic Mathématiques	Docteur en Mathématiques	MCB	Cours. TD	
Sadouki Mustapha	DES Physique des Rayonnements	Docteur en Physique Théorique	MCB	C.TD.Encad_	
Fermous Rachid	DES physique théorique	Doctorat physique théorique	MCB	C.TD. Encad_	
Zaoui Sanaa	DES Physique des Rayonnements,	Magister physique théorique	MAA	C.TD.Encad_	
Debabi Mohammed	DES Physique des Rayonnements	Magister physique nucléaire	MAA	C.TD.Encad_	
Redaouia Kelthoum	DES / Physique théorique	" physique théorique	MAA	C.TD.Encad	
Bitam Tarek	Ingenieur génie nucleaire	Magister Sciences Nucleaires	MAA	Encadrement	
Boudjemaa Fatiha	DES Physique des Rayonnements	Magister physique theorique	MAA	C.TD.Encad_	

*** = Courses, TD, TP, internship supervision, thesis supervision, other (to be specified)**

B: External supervision:

Institution of attachment: Médéa University.

Nom, prénom	Diplôme graduation + Spécialité	Diplôme Post graduation + Spécialité	Grade	Type d'intervention *	Emargement
L. Dekar	DES en Physique	Doctorat en Physique	MCA	C. TD. Encadrement	

*** = Courses, TD, TP, internship supervision, thesis supervision, other (to be specified)**

5 – Specific material resources available

Apart from the fact that the faculty has a large number of physics laboratories, this master does not require practical work in the specialty.

A- Pedagogical Laboratories and Equipment: Sheet of existing pedagogical equipment for the practical work of the planned training (1 sheet per laboratory)

B- Places for work placements and training in companies:

Internship location	Number of students	Internship duration
Energy and smart Systems Laboratory	20	Up to six months

C- Laboratoire(s) de recherche de soutien au master :

Head of the laboratory: Benallal Mohamed Nadjib
Laboratory Approval No.:
Date : 01/03/2016 **Opinion of the head of laboratory: favorable opinion**

D- Master's support research projects :

Title of the research project	Project code	Project start date	Project end date
Determination of the energy spectrum for families relative to the "l" states for families of potentials of exponential form via path integrals	B00L02UN440120140001	01/01/2014	2018
Acoustic characterization of porous materials:	B00L02UN440120140014	2014	2018

E- Spaces for personal work and ICT :

The Science and Technology Faculty of the Khemis Miliana University has several computer laboratories for the practical work of the numerical analysis module, in addition to the reservation of Internet sessions. Also, the energy and smart systems laboratory LESI to which this master is attached has a high-performance computing center, not to mention the multiple reading rooms that will be reserved for them.

II – Half-yearly course organization sheet

1- Semester 1 :

Teaching unit	Matter	Credit	Coefficient	C	TD	TP	Volume (hour)
Fundamental Unit	Advanced Quantum Mechanics I	7	4	3h00	1h30		67h30
	Quantum statistical physics	6	3	3h00	1h30		67h30
	Quantum Field Theory I	6	3	3h00			45h00
Methodological unit	Advanced mathematical method of physics	4	2	1h30		1h30	45h00
	Group theory	4	2	1h30		1h30	45h00
Discovery unit	Nuclei and elementary particles	1	1	1h30			22h30
Transversale Unit	English	1	1	1h30			22h30

1- Semester 1 :

Teaching unit	Matter	Credit	Coefficient	Courses	TD	Practical Work	Volume (hour)
Fundamental Unit	Advanced Quantum Mechanics II	7	4	3h00	1h30		67h30
	Nuclear structure I	6	3	3h00	1h30		67h30
	Quantum Field Theory II	6	3	3h00			45h00
Methodological unit	Numerical programming	5	3	1h30	1h30	1h30	67h30
	Differential geometry and topology	4	2	1h30	1h30		45h00
Transversale Unit	English II	1	1	1h30			22h30

Third Semester

Teaching unit	Matter	Credit	Coefficient	C	TD	TP	Volume (hour)
Fundamental Unit	Quantum information	6	3	3h00			45h00
	Nuclear structure I	7	4	3h00	1h30		67h30
	Path integrals	6	3	3h00			45h00
Methodological unit	General relativity	5	3	1h30	1h30		45h00
	radiation-matter interaction	4	2	1h30	1h30		45h00
Discovery unit	Initiation to research	2	2	1h30			22h30

Semester 4

Internship in a company sanctioned by a thesis and a defense.

	VHS	Coeff	Crédits
Personal Work	350	1	30
Total Semester 4	350	1	30

5- Global summary of the training: (indicate the separate global VH in progress, TD, for the 04 teaching semesters, for the different types of teaching units)

UE / VH	UEF	UEM	UED	UET	Total
Courses	27h00	7h30	1h30	4h30	41h30
TD	9h00	9h00	0	0	18h30
TP	0	01h30	0	0	1h30
Personnal work	350	0	0	0	350
other					
Total	386	19h30	0	0	411h30
Credits	87	26	1	6	**120**
% in credits for each teaching unit	72.5	21.67	0.83	5.0	100.0

III - Detailed program by subject

(1 detailed sheet per subject)

Title of the Master : Theoretical Physics

Semester : 1

Title of the UE : Fondamentale UEF1.1

Subject Title : Advanced Quantum Mechanics I

Credits : 7

Coefficients : 4

Teaching objectives

- To improve the understanding of quantum mechanics.
- Acquisition of the quantum formalism to understand the properties and structure of atoms
- Study a charged particle in a magnetic field and its phenomenological applications.

Recommended prior knowledge

Mastery of the basic concepts and tools of quantum mechanics.

Content of the course

I. Reminder of the wave function and the Schrödinger equation

1 The wave function
2 Interferences and the principle of superposition
3 Free wave packets
4 Impulse measurements and uncertainty relations
5 The Schrödinger equation

2 Quantification of energies of simple systems

1 Bound states and scattering states
2 One dimensional harmonic oscillator
3 Square potential well
4 Periodic boundary conditions
5 Double well; the ammonia molecule
6 Applications of the double well model

3. Kinetic Momentum

1. Kinetic momentum operators and their irreducible representations
2. Eigenfunctions of angular momentum
3. Rotation of a diatomic molecule
4. Composition of angular momentum

4. Hydrogen atom

1. Central symmetric field
2. Study in spherical coordinates
3. Study in parabolic coordinates
4. Fine structure of the energy levels
5. Structure of transitions
6. Fine structure of energy levels, LS coupling and JJ coupling

5. Action of a magnetic field

1. Coupling energy, Zeeman effect of fine structure of the hydrogen atom
2. Zeeman effect of hyperfine structure of the hydrogen atom
3. Magnetic resonance

Evaluation method:

Continuous assessment, examination,

References

1 "Quantum Mechanics I and II" Claude Cohen-Tanoudji, Bernard Diu, Franck Laloé, Hermann 1997
2. "Quantum Mechanics", Claude Aslangul, de Broeck 2015
3. "Advanced Quantum Mechanics", Franz Schwabl, , Third Edition, Springer
4. "Principles of Quantum Mechanics", Shankar R., 2nd ed, 3rd printing (Springer, 2008)
5. "Quantum Mechanics; Volume 3L". Landeau and E. Liftchitz, ;Éditions MIR 1967

Title of the Master : Theoretical Physics
Semester : 1
Title of the UE: Fondamental UEF1.1
Subject Title : Quantum Statistical Physics
Credits : 6
Coefficients : 3

Teaching objectives

Become aware of the cross-disciplinary nature of statistical physics through a wide variety of applications.
Understand the role of statistical physics in contemporary developments in physics.
Perform simple calculations for systems described by stochastic dynamics and determine stationary probability distributions.

Recommended prior knowledge

Quantum mechanics, statistical physics

Content of the subject:

1. Reminders

1.1 Canonical ensemble,
1.2 grand Canonical ensemble

2. Formulation of the quantum statistics

2.1 Statistics of the different ensembles (micro-canonical, canonical and grand canonical),
2.2 Systems of indistinguishable particles,
2.3 Density matrix and partition function for a system of free particles

3. Applications of quantum and classical distributions :

3.1 Black body
3.2 Metals
3.3 Semiconductors
3.4 Phonons

4. Fermion Systems

4.1 Thermodynamic behavior of a real gas of fermions

5. Study of non-equilibrium quantum systems

5.1 External perturbation,
5.2 Liouville and Van Nueman equation,
5.3 Brownian motion,
5.4 Linear response,
5.5 Classical kinetic equation.

Evaluation method:

Continuous assessment, examination,

Reference:

1. B. Diu, C. Guthmann, D. Lederer, B. Roulet: Statistical Physics, Hermann
2. C. Ngô and H. Ngô: Statistical Physics, Dunod
3. F. Reif: Fundamentals of statistical and thermal physics, McGraw-Hill

Title of the Master : Theoretical physics

Semester *: 1*

Title of the UE : Fundamental UEF1.1

Title of the subject : Quantum field theory I

Credits : 6

Coefficients : 3

Teaching objectives

- Understand the concept of canonical quantization for scalar, vector and fermion fields
- Understand the concept of global and local symmetry in quantum field theory and their implications.

Recommended prior knowledge

Quantum mechanics, analytical mechanics, electromagnetism, special relativity

Content of the subject

I. Reminders on quantum mechanics

1.1 - Harmonic oscillator
1.2 -Schrodinger equation
1.3 - Probability density
1.4 -Probability current
1.5 -Pauli equation
Application exercises

II. Reminders on special relativity

2.1-Qudri-vectors: position, space-time derivative, pulse-energy.
2.2 -Equation of conservation of the charge
2.3 -Load density
2.4 -Load current
2.5 Electromagnetic Tensor
-Application exercises

III. Symmetry and invariance

3.1 - Geometric transformations
3.2 -Internal transformations
3.3 -Internal geometrical transformations
Application exercises

IV: Klein-Gordon equation

4.1 -Free Klein-Gordon equation
4.12 -Invariance of the free Klein-Gordon equation by Jauge transformation
4.3 -Solutions of the free Klein-Gordon equation
4.4 - Klein-Gordon equation in the presence of an external electromagnetic field
4.5 -Invariance of the Klein-Gordon equation in the presence of an external electromagnetic field by
Gauge transformation
5.6 -Solutions of the Klein-Gordon equation in the presence of an external electromagnetic field
4.7 - Klein's paradox
Application exercises

V: Dirac equation

5.1 -The shortcomings of the Klein-Gordon equation
5.2 -The properties of Dirac matrices
5.3 - Standard presentation
5.4 -Free Dirac equation
5.5 -Invariance of the free Dirac equation
5.6 -Solutions of the free Dirac equation
5.7 - Relativistic equivalent of the Dirac equation
5.8 -Ultra-relativistic limit of the Dirac equation
Application exercises

Evaluation method:

Continuous assessment, examination,

References

1. J. P. Derendinger, Quantum Field Theory, Presses polytechnique et universitaires romandes, 2001
2. S. Weinberg, Quantum theory of fields, 3 vols, Cambridge University Press, 1995,1996
3. J. J. Sakurai, Advanced quantum mechanics, Addison-Wesley, 1967
4. J. D. Bjorken and S.D. Drell, Relativistic quantum fields, McGraw-Hill, 1965
5. F. Mandl and G.Shaw, Quantum field theory, Addison-Wesley, 1993
6. N. N. Bogoliubov, D. V. Shirkov, Introduction to the Theory of Quantized Fields (Interscience Monographs in Physics and Astronomy), John Wiley & Sons, 1959
7. R. Balian, From Microscopic to Macroscopic, vol. 2. École polytechnique, ellipses, 1982

Title of the Master : Theoretical physics

Semester: 1

Teaching Unit: Methodology UEM 1.1
Subject Title: Advanced Mathematical Methods in Physics
Credits: 4
Coefficient: 2

Teaching Objectives:
To provide students with an overview of the basic concepts and techniques used in the field of Mathematical Physics.

Recommended prior knowledge
Mastery of basic tools in mathematical analysis and algebra.

Course Content:

I. Variational Calculus

1- Ritz's variational principle
2- Euler's equation
3- Variations with constraints and Lagrange multipliers

II. Orthogonal Polynomials

1- Jacobi, Hermite, Laguerre polynomials
2- Generating functions
3- General properties of orthogonal polynomials
4- Legendre polynomials:
   - Legendre's differential equation
   - Properties of Legendre polynomials
   - Integral representation
   - Recursion formula relating Legendre polynomials with their derivatives
   - Second-order Legendre functions

III. Special Functions: Bessel functions

1- Bessel's equation
2- Orthogonality of Bessel functions and their roots
3- Expansion of arbitrary function in terms of Bessel series
4- Hankel functions
5- Bessel functions with imaginary argument.

Mode of evaluation: Continuous assessment 50%, examination 50%

References

1. “Mathematical Methods for Physicists: A concise introduction” Tai L. Chow, Cambridge University Press 2000.
2. “Méthodes Mathématiques pour Physiciens ”, Martin Kunz, Mathias Albert, Mona Frommert, Université de Genève 2011.
3. “ Mathématiques pour physiciens ”, Jean-Bernard Zuber, université Paris-Sud 2013.
4. “ Méthodes Mathématiques de la Physique ”, Xavier Bagnoud, Université de Fribourg 2010.
5. “ Des mathématiques pour les sciences, Cours et Exercices ”, Claude Aslangul, de Broeck, 2011.

Title of the Master : Theoretical physics
Semester: 1
Title of the unit: UEM Methodology 1.1
Title of the subject: Group Theory
Credits: 4
Coefficients: 2
Teaching objectives

To provide the basic tools of group theory so that students master the classical groups used in physics.

Recommended prior knowledge
Higher algebra

Content of the subject

1. General information on Symmetry Groups in Physics

2. Basic notion of group theory

2.1. Groups
2.2. Subgroups
2.3. Classes modulo a subgroup
2.4. Quotient group
2.5. Homomorphism
2.6. Direct and semi-direct group product

3. General information on group representations

3.1. Definitions
3.2. Representation operations
3.3. Typical irreducible and iso representation
3.4. Typical unit and iso representation
3.5. Tensor operators
3.6. Abstract Wigner Eckart theorem

4. Lie groups and Lie algebra

4.1. Infinitesimal properties of Lie groups
4.2. Lie theorems (1st, 2nd and 3rd)
4.3. Taylor's theorem for Lie groups

5. Lie algebras and root space

5.1. classification of lie algebras

5.2. properties of root subspaces
5.3. Cartan criteria
5.4. Properties of Cartan's subalgebra

6. Space of roots and Dynking diagrams

6.1. Classification of simple root spaces
6.2. Dynking diagrams

7. Example of representation of finite or compact groups

7.1. unit groups
7.2. orthogonal groups
7.3. symplectic groups
7.4. SO*(2n) and SU*(2n) groups

References

1. "Group theory in physics" W.K. Tung. World Scientific Publishing

Master title: Theoretical physics
Semester: 1
Title of the unit: Discovery UED 1.1
Subject title: Nuclei and elementary particles

Credits: 1

Teaching objectives

Provide insight into strong and weak interactions

Recommended prior knowledge

Basics of quantum mechanics

Contents:

Chapter 1 : Introductions

- Discovery of alpha, beta and gamma radiations
- origin and composition of cosmic rays
- particle detection principle

Chapter 2 : Discovery of the first elementary particles

- Discovery of the neutron
- Discovery of the pion and the muon
- Discovery of strange particles

Chapter 3 : Strong interaction

- Quark and confinement hypothesis
- Yukawa model
- Strong nuclear interaction and QCD

Chapter 4 : Weak interaction and introduction to the standard model

- Discovery of neutrinos and anti-neutrinos
- Discovery of several neutrino flavors
- Basic assumption of the standard model
- experimental checks (neutral current and bosons W and Z)
- origin of the mass of elementary particles (Discovery of the Higgs boson)

Evaluation method:

Continuous assessment, examination.

References :

1. "Le vrai roman des particules élémentaires" F. Vannucci, Dunod 2010
2. "L'univers des particules", M. Crozon Editions du Seuil 1999

Master title: Theoretical physics
Semester: 1
Title of the unit: Discovery UED 1.1
Subject title: English I
Credits: 2
Coefficients: 2

Teaching objectives

• Master scientific English
• Writing scientific articles in English
• Oral communications in English

Recommended prior knowledge
Good base in English language

Content of the subject

I. English text structure
II. General physics glossary
III. Laboratory instruments description
VI. Scientific Experiment description

Evaluation method:
Continuous assessment, examination.

References
1. “Communicating in English: A practical guide for scientists”, Baud, Dorothée and Lauriane Hillion, ellipses 2010
2. “English: how to translate”, Perrin, Isabelle, Hachette 2010

Title of the Master : Theoretical Physics
Semester : 2
Title of the UE : Fundamental UEF 2.1
Subject Title : Advanced Quantum Mechanics II
Credits : 7
Coefficients : 4

Objectives of the course
To improve the knowledge of quantum mechanics through the study of :
- Stationary and time-dependent perturbation techniques widely used in modern physics.
- Study of collision theory and identical particles,
- Introduce the second quantization

Recommended prior knowledge
Mastery of the basic concepts and tools of quantum mechanics.
Content of the subject
I Stationary perturbations and variational method
1 Stationary perturbation methods
2 Variational method
II Time-dependent perturbation
1 Position of the problem
2 Approximate solution of the Schrödinger equation
3 Perturbation equations
4 Transition probability
5 Sinusoidal perturbation
6 Constant perturbation
7 Fermi's golden rule
8 Adiabatic perturbation
9 Application : Interaction of an electromagnetic wave with an atom .
III Collision processes
1 Notion of effective cross section
2 Quantum calculation in the Born approximation
4 Scattering by a central potential.
3 Exploration of compound systems
IV Identical particles
1 Indistinguishability of two identical particles
2 System of two particles; exchange operator
3 Pauli's principle
4 Physical consequences
V Second non-relativistic quantization :
1 Multibody systems.
2 Bose and Fermi statistics.
3 Fock spaces.
4 Creation and annihilation operators.
5 Canonical commutation and anti-commutation relations.
6 Gas of free bosons and fermions.
7 Descriptions of interactions
Evaluation method:
Continuous assessment, examination.

References

1. L. Landau and E. Lifshitz, Quantum Mechanics, chapter XVII (Mir Publishing, Moscow, 1975).
2. A. Messiah, Quantum Mechanics, chapters XI and XIX (Dunod, Paris, 1995).
3. M. L. Goldberger and K. M.Watson, Collision theory (Wiley, New-York, 1964).
4. N. F. Mott and H. S. W. Massey, The Theory of Atomic Collisions, Oxford Clarendon Press, 1965.
5. C. J. Joachain, Quantum Collision Theory (North-Holland, Amsterdam, 1983).
6. I. Duck and E.C.G. Sudarshan, Pauli and the Spin-Statistics Theorem(World Scientific, ingapore, 1997.

Master title: Theoretical physics
Semester: 2
Title of the unit: Fundamental UEF 2.1
Title of subject: Nuclear structure I
Credits: 6
Coefficients: 3

Teaching objectives:
The objective of study nuclear structure theory used to comprehension the structure of the atomic nucleus, in particular the nature of the interactions between nucleons-nucleons.

Recommended prior knowledge

Atomic and nuclear physics.
Content of the subject
1. General information on the atomic nucleus
    1.1. Binding and separation energy
    1.2. Center of mass and kinetics of nuclear reactions
    1.1. Coulomb and Rutherford cross section
2. Nuclear models
    2.1. Liquid drop model
    2.2. Shell model
        2.2.1. Magic numbers
        2.2.2. Schrodinger equation in mean field not deformed
        2.2.3. Harmonic oscillator and Woods-Saxon potential
        2.2.4. Structure of nucleus
        2.2.5. Spin-orbit interaction
        2.2.6. Electric quadrupole moment
        2.2.7. Magnetic dipole moment
        2.2.8. Nucleus interaction with mean field
3. Nuclear reactions
    3.1. Nuclear transition
    3.2. Scattering theory
    3.3. Diffusion cross section
    3.4. Compound nucleus
4. **Evaluation method:**
5. Continuous assessment, examination.

References

1. Kris L. G. Heyde, Basic Ideas and Concepts in Nuclear Physics, An Introductory Approach, Taylor & Francis, 2004.
2. Walter Greiner and Joachim A. Maruhn, Nuclear Models, Springer Berlin Heidelberg, 2008.
3. Carlos Bertulani, Nuclear Physics in a Nutshell, Princeton University Press, 2007.

Title of the Master : Theoretical physics

Semester *: 2*
Title of the UE : Fundamental UEF 2.1
Title of the subject : Quantum field theory II
Credits : 6
Coefficients : 3

Teaching objectives

The description of particle systems at energies for which the corpuscular (quantum) nature takes precedence over the wave (classical) nature.

Recommended prior knowledge

Quantum field theory I of S2

Content of the subject

I- Lagrangian formulation of the field theory

-Reminder of the Lagrangian formalism in classical mechanics
-Principle of least action
-Euler-Lagrange equations
-Hamiltonian formulation
-Analogy with field theory
-Free field theory
-Conjugate moment of a scalar field
-Lagrangian of the Schrodinger equation
-Basic principle of field theory
-Klein-Gordon field (scalar)
-Complex scalar field
-Complex scalar field in the presence of an external electromagnetic field
-Dirac vector field
-Electromagnetic field
-Lagrangian of the standard model
Application exercises

II- Symmetries, conservation laws and Noether's theorem

-Invariance by space-time transformation
-Invariance by global phase transformation
-Invariance by local phase transformation
-Demonstration of Noether's theorem
-Noether's theorem
Application exercises

III-Quantification of free fields

-Quantification of scalar fields (real and complex) of Klein-Gordon
-Quantification of the Dirac spinor field
-Quantification of the electromagnetic field (Gupta-Bleuler)
Application exercises

VI- Propagators and chronological products

Application exercises

V- Interacting fields

Application exercises

VI- Compton scattering

Application exercises

VII- Faynman diagrams

Application exercises

Evaluation method:

Continuous assessment, examination.

References

1. J. P. Derendinger, Quantum Field Theory, Presses polytechnique et universitaires romandes, 2001
2. S. Weinberg, Quantum theory of fields, 3 vols, Cambridge University Press, 1995,1996
3. J. J. Sakurai, Advanced quantum mechanics, Addison-Wesley, 1967
4. J. D. Bjorken and S.D. Drell, Relativistic quantum fields, McGraw-Hill, 1965
5. F. Mandl and G.Shaw, Quantum field theory, Addison-Wesley, 1993
6. N. N. Bogoliubov, D. V. Shirkov, Introduction to the Theory of Quantized Fields (Interscience Monographs in Physics and Astronomy), John Wiley & Sons, 1959

ellipses, 1982

Title of the Master : Theoretical physics

Semester: 2
Teaching Unit: Methodology UEM 2.1
Subject Title: Numerical Programming
Credits: 5
Coefficients: 3
Teaching Objectives:
Mastery of numerical methods for solving different types of differential equations, as well as some tools for eigenvalue equations

Recommended prior knowledge
• Mastery of Computer Science 1 and 2 (Fortran and Matlab)
• Good knowledge in Numerical Methods and Programming, and Series and Differential Equations taught in the second year of the Bachelor's degree.

Content of the subject

1. **Nonlinear Equations**
   1.1. False Position and Secant Methods
   1.2. Newton-Raphson Method
   1.3. Systems of Nonlinear Equations
2. **Matrix Calculations**
   2.1. Gauss-Jordan Method
   2.2. LU Decomposition
   2.3. Other Methods
3. **Interpolation**
   3.1. Polynomial Interpolation
   3.2. Spline Method
4. **Differentiation**
   4.1. Implicit Finite Differences
   4.2. Explicit Finite Differences
5. **Integration**
   5.1. Trapezoidal, Simpson, and Romberg
   5.2. Gaussian Quadratures
   5.3. Improper Integrals
6. **Ordinary Differential Equations**
   6.1. First and Second Order Equations
   6.2. Heun and Runge-Kutta Methods
7. **Partial Differential Equations**
   7.1. Discretization
   7.2. Finite Element Method
8. **Monte Carlo Method**
   8.1. Principles of the Method
   8.2. Random Number Generators
   8.3. Applications

Evaluation method:
Continuous assessment, examination.

References

1. "Elementary numerical analysis: an algorithmic approach" Samuel Daniel Conte and Carl W De Boor, McGraw-Hill Higher Education, 1980

2. “Numerical analysis ”, Richard L Burden and J Douglas Faires, 7th. Prindle Weber and Schmidt, Boston, 2001
3. “ Numerical recipes 3rd edition: The art of scientific computing ”, William H Press Cambridge university press, 2007
4. “Méthodes numériques: algorithmes, analyse et applications”, Alfio Maria Quarteroni, Riccardo Sacco, and Fausto Saleri, Springer Science & Business Media, 2008

Title of the Master: Theoretical physics

Semester: 1
Title of the unit: UEM Methodology 2.1
Course title: Differential Geometry and Topology
Credits: 4
Coefficients: 2

Teaching objectives

To be able to handle physical theories that use the properties of space (general relativity, string theory, ...)

Recommended prior knowledge

Vector and differential analysis, notion of geometry.

Content of the subject

1.Exterior Algebra
2.Differential Forms on an Open Subset of R^n
3.Metrics on Vector Spaces
4.Elementary Gauge Theory
4.1. Maxwell’s Equations
4.2. Connections - potential
4.3. Curvature - field strength
4.4. Covariant derivative
4.5. Yang-Mills theory

5. Einstein-Cartan Theory
5.1. The Equivalence principle
5.2. Cartan's Structure equations
5.3. Symmetric connections
5.4. Actions and field equations
5.5. The stress-energy tensor
5.6. Einstein gauge
5.7. Geodesics

6. Lie Derivative
7. Differentiable Manifolds
7.1. Definition
7.2. Differentiable Maps
7.3. Submanifolds
7.4. Tangent space
7.5. Tangent bundle
7.6. Vector fields
7.7. Frames
7.8. Tangent Linear Mapping

8. **Differential Forms on a Manifold**
8.1. Orientation
8.2. Poincaré's theorem
8.3. Stokes' theorem

9. Lie Groups, Lie Algebras

10. Differentiable Fiber Bundles
10.1. Definitions Geometry of the Frame Bundle
10.2. Principal bundles
10.3. Reduction of structural Group (Spontaneous Symmetry Breaking)
10.4. Bundle morphisms
10.5. Examples
10.6. Associated bundles
10.7. Sections
10.8. Connections on a principal bundle
10.9. Covariant derivative
10.10. Geometry of the frame bundle
10.11. Parallel Transport
10.12. Holonomy Group
10.13. Gauge Transformation

Evaluation method:
Continuous assessment, examination.

References
1. “Topology and Geometry for Physicists ”, C. Nash, S. Sen, , Dover Books on Mathematics 2011
2 Topology and Geometry for Physicists ”, C. Nash, S. Sen, , Dover Books on Mathematics 2011

Master title: Theoretical physics

Semester: 2
Title of the teaching unit: Discovery
Subject title: English II
Credits: 2
Coefficients: 2

Teaching objectives

- The objective was to develop teaching around scientific English in order to allow students to give them the basics of reading articles in English.
- Mastery of the English language, written and oral (comprehension and expression: correctness, precision, richness), as well as English grammar (rules and analyzes of language facts in context).
- Learn the method of processing scientific texts in English. Introduction to the method of writing a scientific document in English.

Recommended prior knowledge

Good knowledge of English language

Content of the subject

I. Reading and writing
1. Reading a scientific paper
2. Write a scientific experiment summary
3. Introducing a scientific subject
4. Discussing a scientific result
5. Writing a scientific paper

II. Oral communication
1. Preparing an oral communication
2. Work group on paper writing

Evaluation method:

Continuous assessment, examination.

References

1. "A workbook for basic writing composition: Second & third year (English degree)", Zoubir, Abdelhamid, OPU 2007
1. "English: how to translate", Perrin, Isabelle, Hachette 2010
3. "Communicating in English: A practical guide for scientists", Baud, Dorothée and Lauriane Hillion, ellipses 2010

Master title: Theoretical physics
Semester: 3
Title of the unit: Fundamental
Title of subject: Nuclear structure II
Credits: 7
Coefficients: 4

Teaching objectives

The objective of study nuclear structure theory used to comprehension the structure of the atomic nucleus, in particular the nature of the interactions between nucleons-nucleons.

Recommended prior knowledge

Atomic and nuclear physics.

Content of the subject

1. **Deformed mean field**
   1.1. Introduction
   1.2. Mean field models
      1.2.1. Nilsson model
      1.2.2. Woods-Saxon model
   1.3. Hartree Fock method
   1.4. Pairing correlations
      1.4.1. Second quantification hamiltonian
      1.4.2. BCS Theory
2. **Collective model**
   2.1. Nuclear surface parameters
   2.2. Inertia moment and Cranking formula
   2.3. Nuclear multipole moments
      2.3.1. Neutron proton radii
      2.3.2. Electric quadrupole moment
3. **Macroscopic-microscopic model**
   3.1. Introduction
   3.2. Micro-macro approach
   3.3. Nuclear level density
   3.4. Strutinsky shell corrections include the pairing correlations in the BCS approach

Evaluation method:

Continuous assessment, examination.

References

1. Amos de-Shalit and Herman Feshbach, Theoretical Nuclear Physics: Nuclear Structure, Wiley-Interscience, 1990.
2. Aage Bohr and Ben Mottelson, Nuclear Structure, Two-Volume Set, World Scientific Publishing Company, 1998.
3. Ingemar Ragnarsson and Sven Gösta Nilsson, Shapes and Shells in Nuclear Structure, Cambridge University Press, 2005.
4. Peter Ring and Peter Schuck, The Nuclear Many-Body Problem, Springer, 2nd Ed., 2005.

Master title: Theoretical physics
Semester: 3
Teaching Unit: Fundamental UEF 3.1
Subject Title: Quantum Information
Credits: 6
Coefficients: 3

Teaching Objectives

To introduce quantum information and quantum computing.
Recommended Prerequisites Courses in quantum mechanics I and II in the physics bachelor's degree program.

Recommended prior knowledge
Quantum mechanics, analytical mechanics

Course Content:

1- What is a qubit?
1.1. Polarization of light
1.2. Polarization of a photon
1.3. Mathematical formulation: the qubit
1.4. Principles of quantum mechanics
1.5. Quantum random number generator
1.6. Quantum cryptography

2- Manipulations of a qubit
2.1. Bloch sphere, spin 1/2
2.2. Dynamic evolution
2.3. Qubit manipulations : Rabi oscillations

3- Quantum correlations
3.1. States of two qubits
3.2. Density operator and entropies
3.3. The quantum no-cloning theorem
3.4. Bell inequalities
3.5. Teleportation

4- Introduction to quantum computing
4.1. Reversible computing
4.2. Quantum logic gates
4.3. Quantum Fourier transform
4.4. Period of a function
4.5. Physical realizations

Evaluation method:
Continuous assessment, examination.

References
1. Michael Nielsen et Isaac Chuang Quantum Computation and Quantum Information, Cambridge University Press, Cambridge (2000).
2. http ://www.theory.caltech.edu/~ preskill/
3. Valerio Scarani, Introduction _a la physique quantique, Vuibert (2003).
4. M. Le Bellac Physique quantique, EDPSciences Editions du CNRS, (2003).

Title of the Master : Theoretical physics

Semester *: 3*

Title of the UE : Fundamental UEF 3.1

Title of the subject : Path integrals

Credits : 6

Coefficients : 3

Teaching objectives

Introduce students to the approach of quantum mechanics through the formalism of Feynman path integrals

Recommended prior knowledge

Quantum mechanics, analytical mechanics

Content of the subject

1. Introduction to the path Integrals
1.1. Introduction
1.2. Feynman integral
1.3. Trotter's Product Formula
2. Propagators for Quadratic Lagrangians
2.1. Introduction
2.2. Propagator Derivation
2.3. Special Cases
3. Path Integrals in a Generalized Coordinate System
3.1. Introduction
3.2. Integral of Course in Polar Coordinates
3.3. Examples
4. Spatio-Temporal Transformations in Path Integrals
4.1. Introduction
4.2. space- time transformation in Classical Mechanics
4.3. Promoter Concept
4.4. Spatio Temporal Transformation in path Integrals
4.5. Examples

Evaluation method:

Continuous assessment, examination.

References

1. R.P. Feynman, Hibbs, Quantum Mechanics and Path Integrals, McGraw-Hill, New York, 1965.
2. D.C. Khandekar, S.V. Lawande, K.V. Bhagmat, Path IntegralMethods and their Applications, World Scientific, Singapore, 1986.
3. L.S. Schulman, Techniques and Applications of Path Integration, Wiley, NewYork, 1981.

Title of the Master: Theoretical physics

Semester: 3
Title of the unit: UEM Methodology 3.1
Subject Title: General Relativity
Credits: 5
Coefficients: 3

Teaching objectives:
Give students the basics of general relativity
Recommended prior knowledge
Classical mechanics, special relativity

Content of the subject:
1. Introduction
2. Newtonian Gravitation
2.1. The space of inertia and Galilean relativity
2.2. principle of inertia and Galilean relativity
2.3. Newtonian gravity
3. Special relativity
3.1. Michel and Morley experiment
3.2. The spacetime of special relativity
3.3. Relativistic Covariant Form of the Laws of Physics
4. Gravitation and Special Relativity
4.1. The gravitational redshift
4.2. The curvature of light rays
4.3. The advance of Mercury's perihelion
4.4. Need for nonlinear equations
5. Tensor Calculus
5.1. Varieties
5.2. Vector fields
5.3. Tensor fields
5.4. Metric tensor
5.5. Exterior differential forms
5.6. Notation tensorial
6.The Principal of Equivalence
6.1. The principle of weak equivalence
6.2. Principle of equivalence and minimum coupling
6.3. The gravitational redshift
6.4. Geodesic motion
6.5. Geodetic deviation
6.6. Other classic tests
7. Einstein's Equations
7.1. The energy momentum tensor
7.2. Einstein's equations
7.3. Schwarzschild's solution
7.4. Local geometry of Friedman spaces
7.5. Other metrics of astrophysical interest
7.6. Variational form of field equations
7.7. Linearization of Einstein's equations
7.8. Gravitational waves and radiation
Evaluation method:
Continuous assessment, examination.

References

1. Wolfgang Pauli; Theory of relativity, Dover Publications, Inc. (1981)
2. R. Penrose Encyclopedia of Mathematical Physics - General Relativity Overview, Elsevier, 2006
3. http://www.lmpt.univ-tours.fr/~linet/coursRG.pdf
4. http://ipht.cea.fr/Docspht//articles/t09/346/public/Cours2009.pdf
5. http://www.luth.obspm.fr/IHP06/

Title of the Master: Theoretical physics

Semester*: 3*

Title of the TU: Methodological MTU 3.1

Title of the course: Radiation Interaction in Matter

Credits: 4

Coefficients: 2

Teaching objectives:

An introduction to Introduction to electromagnetic and corpuscular radiations as well as their effects on matter

Recommended prior knowledge

Structure of matter, electromagnetism

Content of the subject

I. Characteristics of radiations

1. Electromagnetic radiations
2. Corpuscular radiations

II. Interaction of electromagnetic radiation with matter

1. Fundamental effects: photoelectric, Compton, electron-positron pair production
2. EM radiation attenuation in matter

III. Interaction of charged particles with matter

1. Interaction of electron and positron with matter
2. Interaction heavy ions with matter
3. Energy loss, stopping power and range of ions in matter

IV. Interaction of neutral particles with matter

1. Interaction of neutron with matter
2. Interaction of neutrinos with matter

V. Biological effects of radiations

1. Origin of biological effect
2. Molecular lesions and cellular damage
3. Pathological effects (deterministic and stochastic) of radiation on humans

Evaluation method:

Continuous assessment, examination.

References

- https://www-fourier.ujf-grenoble.fr/~faure/enseignement/matiere-rayon/cours.pdf
- http://e-cours.univ-paris1.fr/modules/uved/envcal/html/rayonnement/2-rayonnement-matiere/2-1-interaction-rayonnement-matiere.html

Master title: Theoretical physics

Semester: 3
Title of the unit: Discovery UED 3.1
Subject title: Initiation to research
Credits: 2
Coefficients: 2

Teaching objectives

The objective of this subject is to provide students with the first concepts and methods essential to scientific observation and the critical analysis of scientific reality.

Recommended prior knowledge

Content of the subject

I. Research in education and science.
II. Methodological orientations
III. Data collection techniques
VI. Data processing techniques.

Evaluation method:

Continuous assessment, examination.

References

1. Dominique Lecourt et Thomas Bourgeois, « *Dictionnaire d'histoire et philosophie des sciences* », Presses universitaires de France - PUF, coll. « Quadrige Dicos Poche », 2006, 4e éd
2. Jean-Marie Nicolle, « *Histoire des méthodes scientifiques, du théorème de Thalès au clonage* », Bréal, 2006