UNIVERSITY
OF TRENTO - Italy

Department of Physics

Doctoral Programme in Physics

Academic year 2014/2015

SYLLABUS

(ANNEX TO THE TRAINING PROGRAMME)

Each PhD student must attend courses corresponding to 12 credits by choosing advanced courses organized:

- by the Doctoral Programme in Physics
- by the Master degree in Physics, or by other similar Master degree courses
- by other similar Doctoral programmes

Other mandatory activities include:

- Research activity followed by a tutor assigned by the Doctoral Programme Committee.
- Attendance of seminars organised by his/her own Research group
- Attendance of Dialogues, Colloquia and Joint Colloquia organized by the Department of Physics also on topics different from the research activity carried out by the PhD students.

Each student must submit his/her study plan to the Doctoral Programme Committee for the approval**.** The study plan must be previously agreed with the tutor.

The credits should be achieved within the end of the first year with the extension to the first semester of the second year only for Master degree courses activated in that time (for up to 6 credits).

PhD students can obtain up to 3 credits for the attendance of International Schools (Summer/ Winter school, etc.) upon the authorization by the tutor and the Doctoral Programme Committee and after passing an exam.

UNIVERSITY
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Department of Physics

Doctoral Programme in Physics

List of courses organized by the Doctoral Programme in Physics a.y. 2014/2015

Docente	Corso	Crediti	Ore
I. LAZZIZZERA	**ADVANCED COURSE ON FUNDAMENTAL INTERACTIONS**	3	21
G.A. PRODI, R.S. BRUSA (COORDINATORI)	**ADVANCED TECHNIQUES IN EXPERIMENTAL PHYSICS**	3	21
P. FORNASINI	**APPLICATIONS OF SYNCHROTRON RADIATION**	3	21
F. DALFOVO G. FERRARI	**ATOMIC PHYSICS AND COLD GASES**	3	21
A. DIAZ TORRES	**QUANTUM SCATTERING THEORY FROM A TIME-DEPENDENT PERSPECTIVE**	3	21
M. FERRARI	**OPTICAL AND SPECTROSCOPIC DIAGNOSTIC OF MATERIALS FOR PHOTONICS**	3	21
V. EFROS	**SCATTERING THEORY**	3	21
M. CERDONIO	**SPACE-TIME AND GRAVITATION: AN EXPERIMENTALIST OVERVIEW**	3	21
G. ORLANDINI	**THEORY OF ELECTROMAGNETIC INTERACTIONS WITH MATTER**	3	21
TALENT (TRAINING IN ADVANCED LOW-ENERGY NUCLEAR PHYSICS)	**FEW-BODY METHODS AND NUCLEAR REACTIONS**	6	45
ECT* (EUROPEAN CENTRE FOR THEORETICAL STUDIES IN NUCLEAR PHYSICS AND RELATED AREAS)	**ECT* DOCTORAL TRAINING PROGRAMME 2015**	*	
SISSA (SCUOLA INTERNAZIONALE SUPERIORE DI STUDI AVANZATI)	**COURSES TO BE DEFINED** (TOPICS: PHYSICS OF MATTER ASTROPARTICLE PHYSICS)	**	
CIAL	**TECHNICAL AND SCIENTIFIC ENGLISH (LEVEL B2)**	***	24

*up to 6 credits

**up to 6 credits

***up to 6 credits in addition to the 12 mandatory credits.

ADVANCED COURSE ON FUNDAMENTAL INTERACTIONS, PROF. I. LAZZIZZERA

Prerequisites

Prerequisites are knowledge of fundamentals in Electroweak and Hadron Physics, as well as in Relativistic Quantum Field Theories.

Contents

Programme

- General features of the Standard Model. Z and W production and decays.
- The search for the higgs particle: day update from the LHC.
- CP violation: Physics at the LHC and SuperB.
- Supersymmetries and Dark Matter candidates: update from the LHC.

Schedule

Schedule: to be agreed with interested students;

Exam

A short presentation on an argument the student wants to choose

Bibliography

Lecture notes will be available.

ADVANCED TECHNIQUES IN EXPERIMENTAL PHYSICS, PROFF. R.S: BRUSA E G. A. PRODI

Prerequisites

The knowledge of a physics graduate is requested.

Contents

This course is organized as a collection of 4-5 lecture cycles on different topics in advanced experimental physics. Each cycle is given by an invited scientist and consists in about 5-6 hours of lectures. The topics are selected every year in experimental research areas of interest of the physics department, giving priority to topics not already discussed in other dedicated PhD courses, as for instance:

1) Antimatter experiments, anti-hydrogen, positron beams, use of positronium in material studies;
2) Applications of particle beams in medicine;
3) Biophysics, in particular methods for the conditioning/investigation of single biological molecules and for the imaging;
4) Cold gases condensates, atomic interferometry;
5) Fundamental noise limits in motion detectors, standard quantum noise limit, ;
6) Instrumentation and methods for observational astrophysics and cosmology;
7) Instrumentation and methods in condensed matter and glasses and in surface science;
8) Particle and radiation detectors;
9) High energy Physics;
10) Photonic devices;

The selection of topics of the course depends also on the availability of lecturers from coming from other research institutes. The schedule of the course has to match the agenda of the lecturers and it is provisionally planned.

Schedule

Period: **between January and June 2015**
Further information:
brusa@science.unitn.it; giovanniandrea.prodi@unitn.it

Exam

Bibliography

APPLICATIONS OF SYNCHROTRON RADIATION, PROF. PAOLO FORNASINI

Important note: If the course "Interaction of X Radiation with Matter", proposed for the 2nd level degree in Physics (laurea magistrale), is activated in the second semester, the interested PhD students are asked to take this course, or part of it, in substitution of "Synchrotron Radiation and its applications".

Prerequisites

Prerequisites: basics of special relativity and classical electrodynamics, time-dependent perturbation theory.

Contents

The course aims at a phenomenological review of synchrotron radiation properties, generation and some of the main applications.

Preliminary contents
1 - General introduction to Synchrotron Radiation
Emission of electromagnetic radiation from accelerating charges, the relativistic case
Main properties of synchrotron radiation: angular distribution, spectral distribution, time structure, polarization
2. - Synchrotron Radiation generation and use
Storage rings, structure and operation - Bending magnets and insertion devices: wigglers, undulators, free-electron lasers - Beamlines and their optical components
3 - Overview of the main techniques utilizing Synchrotron Radiation
Properties of X-rays - Absorption and photoemission spectroscopy - Elastic and inelastic scattering - Imaging
4 - Elastic scattering - Diffraction
Basics of X-ray scattering, resonant scattering - Wide angle scattering from crystalline and non-crystalline samples, temperature effects - Small angle scattering - Comparison with elastic neutron and electron scattering
5 - Absorption spectroscopy - EXAFS
Basic principles of photoionisation - Theory of EXAFS - Experimental apparatuses and data analysis procedures - Main applications of EXAFS
6 - Inelastic scattering [the lectures will be given by prof. Giulio Monaco]
Cross-section for non-resonant inelastic scattering - The dynamic structure factor – Optical components required for an inelastic scattering experiment – Examples of experimental results obtained in crystalline and disordered materials

Schedule

The lectures will be given from February to May 2015 (two hours per week).

Exam

The final exam consists in a seminar (approximately 30-40 minutes) on a subject, chosen by the student, connected to synchrotron radiation and its applications: the subject can directly pertain to his research interests or can be a review of some recent research papers.
One or more days (depending on the number of students) will be dedicated to the seminars, no later than the end of June.

References

The slides will be at disposal of students.
References on specific subjects will be suggested during the course.

Bibliography

References.
The slides will be at disposal of students.
References on specific subjects will be suggested during the course.

ATOMIC PHYSICS AND COLD GASES – PROF. FRANCO DALFOVO AND DR. GABRIELE FERRARI

Prerequisites

Basic knowledge of quantum mechanics, quantum statistics and physics of matter.

Contents

The course is divided in two main parts: an introduction to the theory of quantum gases and superfluidity (F.Dalfovo) and an introduction to the experimental methods for the investigation of quantum atomic gases (G.Ferrari).

Schedule

The course starts at mid February and will last for about 11 weeks.

Exam

The exam consists of an oral discussion of a subject chosen by the student among the topics presented in the course.

Bibliography

L. Pitaevskii and S. Stringari, "Bose-Einstein Condensation", Oxford Science Publications, Int. Series of Monographs on Physics, Clarendon Press (2003);

C.J. Pethick and H. Smith, "Bose-Einstein Condensation in Dilute Gases", Cambridge University Press (2008);

F. Dalfovo, S. Giorgini, L. Pitaevskii, and S. Stringari, "Theory of Bose-Einstein condensation in trapped gases", Rev. Mod. Phys. 71, 463 (1999);

S. Giorgini, L. Pitaevskii, and S. Stringari, "Theory of ultracold atomic Fermi gases", Rev. Mod. Phys, 80, 1215 (2008);

W. Ketterle, D.S. Durfee, D.M. Stamper-Kurn, "Making, probing and understanding Bose-Einstein condensates", arXiv:cond-mat/9904034;

W. Ketterle, M.W. Zwierlein, "Making, probing and understanding ultracold Fermi gases", arXiv:0801.2500.

QUANTUM SCATTERING THEORY: A TIME-DEPENDENT PERSPECTIVE – DR. ALEX DIAZ TORRES

Prerequisites

Non-relativistic quantum mechanics and basics of linear algebra.

Contents

This course provides practical tools for quantifying quantum reaction dynamics of composite particles ranging from molecules to complex atomic nuclei. It will introduce numerical methods for solving the time-dependent Schroedinger equation and extracting reaction observables from the time-dependent wave function. Simple Hamiltonians are used and related to problems of interest in different fields.

Contents:

- The time-dependent Schroedinger equation. Hamiltonian and time evolution operator.
- The free-particle wavepacket. Coordinate and momentum representations.
- The Gaussian wavepacket.
- The time propagation of wavepackets. The split operator method and the Chebyshev propagator.
- Correlation functions and spectra.
- One-dimensional barrier scattering of pointlike particles.
- Reflection and transmission coefficients.
- Scattering of composite particles. The coupled reaction channels method.
- Full-dimensional wavepacket dynamics.
- The energy analysis of time-dependent wave functions. The window operator method.

Schedule

To be defined with the instructor, but tentatively in the period March – May 2015.
Contact: torres@ectstar.eu

Exam

Student seminars on the solution of selected problems given by the instructor.

Bibliography

David J Tannor, Introduction to Quantum Mechanics: a Time-Dependent Perspective (University Science Books, Saulito, California, 2007).

OPTICAL AND SPECTROSCOPIC DIAGNOSTIC OF MATERIALS FOR PHOTONICS, DR. MAURIZIO

FERRARI

Prerequisites

The typical skills of a Physics graduate are requested.

Contents

Phenomenological course

Programme

- Introduction to Glass Photonics
- From bulk to nano- and microscale photonics systems
- Rare earth – activated glasses
- Photonics devices fabrication and assessment
- Radiative and non-radiative transitions
- Transition probability
- Energy transfer
- Absorption and emission cross sections; Quantum efficiency
- Light scattering for characterization of material properties
- Confined structures: Planar waveguides
- Confined structures: Nanospheres
- Confined structures: Direct and inverse opals
- Confined structures: Spherical Microresonators
- Confined structures: 1D - Microcavities
- Nanocomposites systems and transparent glass ceramics
- Energy conversion
- Plasmonic structures
- SERS
- Fluorescence enhancement using different sensitizers – metallic and semiconductor nanoparticles, lanthanides ions, nanocrystals.
- Solar energy conversion by quantum cutting.

Schedule

November 2014 - January 2015

Exam

Seminar and discussion

Bibliography

specific papers and books will be suggested during the lectures

SCATTERING THEORY, PROF. V. EFROS

Prerequisites

The significance of scattering theory is due to the fact that our knowledge on structure of matter at any level is gained via studies of scattering and reactions. The objective of the course is to provide the understanding of essentials of scattering theory. Herewith general wave phenomena are considered and quantum mechanical reasonings and estimates are performed as well.

Content

- Free Motion of Wave Packets and Dispersion Phenomena
- Time Evolution of Interacting Wave Packets and Outcome of Scattering Processes
- Cross Section. Incoherence Conditions for Scattering on Many Centers.
- Thin Targets. Cross Section in Terms of Scattering Amplitude. Optical Theorem
- Separation of Center{of{Mass Motion in Particle{Particle Scattering.
- Center{of{Mass and Laboratory Cross Sections
- Approaches to Calculate Scattering Amplitude
- Space{Time Picture of Scattering
- Scattering in Terms of Transition Operators
- Born Approximation.
- Its Properties and Applicability in Atomic and Nuclear Collision Problems
- Phase shifts. Scattering Amplitude in Terms of Phase Shifts
- Behavior of Phase Shifts at Low and High Energies
- Concept of Pseudo-potential and its Applications
- Resonant Scattering.
- Quasi-stationary States. Interplay Between Scattering and Decay of Quasi-stationary States
- Scattering in Systems of Identical Particles

Schedule

Course of 21 academic hours. Lectures each week in Spring 2015

Exam

Two options at the discretion of a student:
1. A discussion over the contents of the course.
2. The presentation of a topic from the course in the presence of other students.
Any materials are allowed to be used in the course of the exam since the main point is the understanding of physics.

Bibliography

Books appropriate for students in the present connection are not available. A written version of each lecture will be given to the students in parallel with the oral presentation.

SPACE-TIME AND GRAVITATION: AN EXPERIMENTALIST OVERVIEW, PROF. MASSIMO CERDONIO

Prerequisites

Basic courses in Physics and in Mathematical Methods

Contents

The course will present and discuss past, recent and contemporary experiments and observations in the physics of space-time and gravitation on Earth and its vicinities and in the Cosmos. The initial focus will be to introduce special and general relativity from an experimentalist view, by discussing classic tests and experiments, both in the original and in the recent high tech realizations. Then it will be discussed on one hand the impact of the forthcoming gravitational wave astronomy on fundamental physics and cosmology, and on the other hand the chances of precision experiments to explore the realm of the Planck regime. The balance between the two parts of the course will be modulated according to the interests and desires of the students.

From space & time to space-time.

• Inertial observers, light and clocks: light speed experiments and realization of inertial frames with clocks and light signals

• Length contraction from a simple exp in electrostatics: Lorentz transformations; relativity of simultaneity; time dilation and the “twins”; Doppler effect; Cerenkov effect.

• Mass and energy: $E=mc^2$; experiments with photon absorption and emission, Compton effect, particle colliders

• Accelerated motion (linear): constant acceleration, “event horizon”, limits to interstellar travel, the accelerated "twins"

• Accelerated motion (rotation): Foucault pendulum, Sagnac effect and gyrolasers, gyromagnetic effects of Barnett and Einstein-DeHaas, Thomas precession.

From the Equivalence Principle to gravity curving space-time.

• Uniqueness of paths in gravitational fields: inertial mass and gravitational mass, esperiments from Galileo and Newton to Eotvos and Roll-Krotkov-Dicke and Adelberger; the Equivalence Principle, EP

• Limits on contributions from different fundamental interactions; Moon telemetry and the Nordvedt effect; experimental limits on EP
• Local inertial frames; "drag free" satellites
•EP and clocks in gravitational fields: gravitational "red-shift"; experiments by Leschiutta, Pound&Rebka, Hafele&Keating, Alley and by Vessot& Levine; the Global Positioning System, GPS
• Gravity affects standard clocks in a flat space-time vs. gravity curves space-time. Heuristic construction of metrics of curved space-time as small perturbation to Minkowski metrics: uniform rotation, weak gravitational field
• Post-Newtonian Parameterization (PPN): parameters α, β, γ for experimental tests on alternative theories

Space-time and gravitation
• The metric outside a central non-rotating mass: the Schwarzschild metric; Newtonian limit; space curvature contribution to post-Newtonian metric
• Coordinates and measurements: radar distance, parallax, etc; gravitational red shift; escape velocity
• Orbits of test particles and of photons: first integral of eq of motion, symmetries and conservations
• The Schwarszchild radius: far from, close to, crossing it; black-holes
• The "classical" tests of General Relativity within PPN: α, β, γ and limits on alternative theories; perihelium of Mercury; light deflection and the Shapiro delay in the solar system
• Orbiting gyroscopes: the DeSitter precession
• Linearized relativistic gravitation "Maxwell-like": "gravitomagnetism" and "gravitational waves"; Schiff precession and Lense-Thirring dragging of inertial frames: recent measurements with GP-B and LAGEOS; gravitational lensing and searches for dark objects – planets, small black-holes, etc ; evidence for emission of gravitational waves: the Hulse & Taylor binary pulsar, the double pulsar binaries.

Experiments and observations in relativistic gravitation
To be given in the second part of the course > not enough time for all the matters listed below > will choose subject(s) with the students
•Towards a new "gravitational wave astronomy" before 2020: coalescing and merging black-hole and neutron star binaries versus detection capabilities of earth and space interferometers: LIGO/Virgo/KAGRA/GEO-HF and LISA
• Fundamentals of GR, cosmography and cosmology with gw observations: GR in the strong field regime; "black" supermassive objects in the galactic nuclei as the Kerr black holes of GR; black holes "thermodynamics"; black hole binaries as "standard sirens" to get "unaided" the Hubble constant and the dark energy equation of state; black holes and cosmic evolution; the impact on cosmology of the observation of a gw cosmological background
• Beyond GR and QM: the quest for experiments on a "minimal length" and on "generalized uncertainty principle"

Schedule

Available to start early December for 3/5 of the course before Christmas; would lecture in the morning of two consecutive days (no preference which, within the week)
Contact for further info: cerdonio@pd.infn.it

Exam

In two parts: *first* the student will give, before the end of the lectures, a 20' presentation on a specific topic related to the course, and, *second*, will give an oral exam on other parts of the course in a session to be held not later than few weeks after the end of the lectures

Bibliography

Books

"Introduction to relativity" J.B.Kogut (Harcourt/Academic Press 2001)
"Special relativity" A.P.French (Chapman & Hall 1991)
"Gravity" James.B.Hartle (Addison Wesley 2003)
"Relativity Special, General and Cosmological" W.Rindler (II edition Oxford Univ. Press 2006)
"General Relativity" M.P.Hobson, G.Efstathiou and A.N.Lasenby (Cambridge 2006)

References

"The Confrontation between General Relativity and Experiment" C. M. Will, Living Reviews in Relativity **9** (2006) http://relativity.livingreviews.org/
"Gravitational waves: from discovery to astronomy" M. Cerdonio and G. Losurdo, La Rivista del Nuovo Cimento **35** (2012)389.
A number of papers on various aspects as paradoxes, more detailed/simplified calculations, historical matters, etc from major journals as Am.J.Phys., Gen. Rel. Gravitation, Class. Quantum Grav., and from the arXiv will distributed to the students, according to their interest and demands.

THEORY OF ELECTROMAGNETIC INTERACTIONS WITH MATTER, PROF. G. ORLANDINI

Prerequisites:

Theory of the electromagnetic field and quantum mechanics.

Aims

The scope of the course is to give the students the unified theoretical background to understand the form of the different electromagnetic cross sections: real/virtual photo-absorption (emission), elastic and inelastic, inclusive and exclusive, Raman and Compton).

Contents

- Derivation of the elastic electron scattering cross section in first order perturbation theory (one photon exchange approximation);
- Discussion on the different target possibilities: point-like, extended, many-body systems;
- Extension to the inelastic reactions: inclusive, semi-inclusive and exclusive cross sections;
- Discussion on the charge and current parts of the cross section;
- Relation between the photo-absorption cross section and the current cross section;
- Relation between the photo-absorption cross section and the charge cross section at low momentum transfer (multipole expansions and Siegert theorem);
- Relation between the neutron scattering cross section and the charge cross section;
- Extension to second order perturbation theory: Compton and Raman scattering.
- Extension to weak interaction (neutrino scattering);
- Relations between first and second order cross sections and the "linear response";
- Sum rules.

Schedule

End of November 2014 – February 2015

Exam

student seminars

Bibliography:

- Lecture Notes

- T. de Forest and J. D.Walecka, Advances in Physics, vol. 15, Issue 57, p.1-109, 1966

- J.D. Bjorken and S.D. Drell "Relativistic Quantum Mechanics" Mc Graw Hill 1964

TALENT 2015

Programme not yet available http://www.ectstar.eu/

ECT* DOCTORAL TRAINING PROGRAMME 2015

Programme not yet available http://www.ectstar.eu/

SISSA

Courses of the Master degree in Physics (http://web.unitn.it/en/dphys/6763/calendar-and-timetable)
Starting in the second semester of the a.y. 2014/2015 (February 2015)

TECHNICAL AND SCIENTIFIC ENGLISH (LEVEL B2)

Prerequisites

Entry level: B1b

Schedule

Presumably in January 2015 – intensive course (with at least 10 students).