Graduate program in Physics
Federal University of Rio de Janeiro

Mandatory Courses for the master and Ph.D degrees
Offered every semester

STATISTICAL MECHANICS (FIW 701/801)

Topics: Thermodynamic potentials: Response functions, determination of the state of equilibrium; Liouville equation: Ergotic hypothesis. Micro-canonical, canonical and grand canonical ensembles; Thermodynamics of phase transitions: Virial expansion. Van der Waals gas. Binary mixtures. Landau model. Curie point. Ginzburg-Landau model. Superconductors. Critical exponents; Ising's model and others: Eistein's fluctuation theory. Correlation and response functions. Scale theory of Widom and Kadanoff. Gaussian model. Model S4. Renormalization group. Calculation of critical exponents; Probability theory: Stochastic variables and distributions. Markov chains. Master equation. Fokker-Planck equation; Boltzman equation: Onsager relations. Fluctuation-dissipation theorem.

Bibliography: L.E. Reichl, A Modern Course in Statistical Physics; Stanley, Introduction to Phase Transitions and Critical Phenomena; K. Huang, Statistical Mechanics; N. Goldenfeld, Lectures on Phase Transitions and the Renormalization Group; Gardiner, Handbook of Stochastic Methods

QUANTUM MECHANICS I (FIW 743/843)

Topics: Review of the Fundamentals of Quantum Theory. Postulates. Hilbert spaces. States and Possibilities. Canonical quantization. Dirac formalism. Temporal evolution. Description of Schrödinger, Heisenberg and Interaction. Symmetries and conservation laws. Notions of group theory. Tensor product of states. Review of simple quantum systems: steady states, wave pack dynamics, harmonic oscillator. Coherent states. Introduction to the formulation of quantum mechanics with path integrals. Density matrix. Rotations, angular momentum, ½ spin particles, orbital angular momentum, addition of angular momentum. Wigner-Eckart theorem. Bell's entangled states and inequalities. Approximation methods: perturbative methods for stationary states and for discrete spectra. Semi-classical methods. Central potentials. Discrete spectrum. Continuous spectrum of a short-range potential and scattering states. Hydrogen atoms. Thin and hyperfine structure. Zeeman and Stark effects.

Bibliography: Modern Quantum Mechanics, J. J. Sakurai; Quantum Mechanics, E. Merzbacher.

CLASSICAL ELECTRODYNAMICS (FIW 704/804)

Topics: Maxwell's Equation in Vacuum and Dielectric Materials: Green's Potentials and Functions; conservation laws; symmetries; Poynting's theorem; Maxwell tension tensor; magnetic monopoles; Electromagnetic Waves in Dielectrics and Conductors: Polarization of electromagnetic waves; reflection and refraction of electromagnetic waves; dispersion of electromagnetic waves; Kramers-Krönig relations; diffraction of electromagnetic waves; scattering of electromagnetic waves; Electromagnetism and Superconductivity: Electromagnetic properties of superconductors; London equations; Special Relativity: Lorentz Transformations; Covariant formation of Maxwell's equations; Lagrangian and Hamiltonian formalism for a particle system and electromagnetic field; Radiation from an Accelerated Charge: Liénnard-Wiechert potentials and fields from a point charge; radiated power; Larmor's formula; Thomson scattering of radiation; Abraham-Lorentz model for electrodynamics: electron self-interaction; concept of electromagnetic mass; Reaction force of radiation.

Bibliography: Classical Eletrodynamics, J. D. Jackson; Continuous Media Electrodynamics, Landau and Lifshitz; Classical Charged Particles, F. Rohrlich.

TEACHING PRACTICE A (FIW 740/840) - 1 credit

Description: This course aims to provide teaching experience to the graduate students. The students will take classes, preferably of a review or practical nature (exercises or laboratory) at undergraduate level. The weekly workload in the classroom is 1 (one) hour. The activities performed by the student will be supervised by a professor of the undergraduate course. This professor will also be responsible for forwarding his final assessment (along with a report of the work done by the student) to the Graduate Coordinator. The student's grade will be an average of that given by the professor, with that given by the Graduate Council after the analysis of the report. The student will not be responsible for class evaluation.

Mandatory Course only for the Ph.D. degree
Offered every semester

QUANTUM MECHANICS II (FIW 744/844)

Topics: Elastic Scattering. Consequences of Conservation of Probability and Angular Momentum. General Properties of Elastic Amplitudes. Born approach. Partial waves. Spread across a Coulomb field. Particle Scattering with Spin. Inelastic collisions. Atomic collision processes. Matrix S. Resonances. Identical Particle Systems. Second Quantization. Application: BCS model at zero temperature. Medium Field Approach. Scattering of Identical Particles. Relativistic Quantum Mechanics. Klein-Gordon equation. Dirac equation. Electromagnetic Interaction of a Dirac Particle. Scattering of ultra-relativistic electrons. Coulomb Field.. Quantization of the Electromagnetic field. Vacuum fluctuations. Radioactive Transitions. Photon scattering. Resonant Scattering and Spontaneous Decay.
Bibliography: Modern Quantum Mechanics, J. J. Sakurai; Quantum Mechanics, E. Merzbacher.

Optional courses, regularly offered

MATHEMATICAL METHODS (FIW 703/803)

Topics: Functions of complex variables; Dispersion relations; Integral transforms; Green functions; Integral equations; Groups and representations; Symbolic computation methods.
Bibliography: Mathematical Methods for Physicists, G. Arfken; Mathematics of Classical and Quantum Pysics, F.W.Byron and R.W. Fuller, Methods of Theoretical Physics, P.M. Morse and H. Feshbach; Integral Equations, F.G. Tricomi.

EXPERIMENTAL METHODS IN CONDENSED MATTER PHYSICS (FIW 705/805)

Topics: Expository part: Each time this discipline is taught, the professor presents a proposal, with the bibliography to be adopted, to the Graduate Deliberative Committee for examination and approval. The proposal must necessarily cover three or more topics listed below: 1) Magnetism; 2. Vacuum and Low Temperature Techniques; 3. Optical spectroscopy; 4. Magnetic Resonance; 5. Preparation and Characterization of Materials.
Description of the Practical Part: The laboratory activities will consist of the execution of at least one experience, not necessarily original, involving experimental techniques covered in the expository part. This activity must be evaluated by the Professor, responsible for the course through an individual report of the student on the experience (s) made.
Bibliography: Methods of Experimental Physics: Volumes 6A and 6B, Solid State Physics. Ed. By K. Clark-Horovitz and V. A. Johnson (1959), Volume 11, Solid State Physics. Ed. By R.V.Coleman (1974), Volumes 13A and 13B, Spectroscopy. Ed. By D. Williams (1976), Volume 21, Solid State: Nuclear Methods. Ed. By J.N.Mundy, S.J.Rothman, M.J.Fluss and L.C.Smedskjaer (1983); Editor-in-chief (founder) L.Marton, Academic Press; Introduction to Nonlinear Laser Specxtroscopy, M.D.Levenson (Academic Press 1982); Photoaccoustical and Photoaccoustic Spectroscopy, A.Rosencwai

GENERAL RELATIVITY (FIW 706/806)

Topics: Special Relativity; The Space-Time of General Relativity; The Curvature Tensor; Gravitation Field equations; Solutions to Einstein's Equations; Classical Tests of General Relativity.
Bibliography: Introducing Einstein’s Relativity, Ray D’Inverno; A First Course in General Relativity, B. F. Schutz; Gravitation and Spacetime, H. C. Ohanian and R. Ruffini; General Relativity, R. M. Wald; Gravitation and Cosmology, S. Weinberg.

COSMOLOGY (FIW 707/807)

Topics: The Observed Universe; The Standard Model of Cosmology; Thermal History of the Universe; Inflationary Models of the Universe; Formation of Structures; Dark matter
Bibliography: Principles of Physical Cosmology, P. J. E. Peebles; The Early Universe, E. W. Kolb and M. S. Turner; Structure Formation in the Universe, T. Padmanabhan; The Deep Universe, A R. Sandage; Gravitation and Cosmology, S. Weinberg.

QUANTUM OPTICS I (FIW 708/808)

Topics: Classical Theory of Coherence, Quantum Theory of Coherence, Interaction of Radiation with Atomic Systems, Maxwell-Bloch Equations, General Techniques for the Treatment of Systems Interacting with Reservoirs, Interaction of Radiation with Atomic Systems: Heisenberg-Langevin Equations.
Bibliography: Optical Resonance and Two-Level Atoms (Wiley, N. Y., 1975), L. Allen and J. H. Eberly; Photons et Atomes: Procesus d'interaction (Inter Editions / Editions du CNRS, Paris, 1988), C. Cohen-Tannoudji, J. Dupont-Roc and G. Grynberg; Optical Coherence and Quantum Optics (Cambridge University Press, Cambridge, 1995), L. Mandel and E. Wolf; Introduction to Quantum Optics (Gordon and Breach, N. Y., 1973), H, M. Nussenzveig; Laser Physics (Addison Wesley, Reading, MA, 1974), M. Sargent III, M. O. Scully and W. E. Lamb, Jr; Quantum Optics (Springer, Berlin! 994), D. F. Walls and G. J. Milburn.

QUANTUM OPTICS II (FIW 709/809)
Topics: Laser Theory, Instability in Lasers, Optical Bistability, Quantum Electrodynamics in Cavities, Solitons, Production and Detection of Compressed States, Parametric Amplification, Cooperative Effects.
Bibliography: Photons et Atomes: Procesus d'interaction (Inter Editions / Editions du CNRS, Paris, 1988), C. Cohen-Tannoudji, J. Dupont-Roc and G. Grynberg; "Sub-Poissonian Processes Quantum Optics", Reviews of Modern Physics 68, 127 (1996), L. Davidovich, Physics Reports 93, 301 (1982), M. Gross and S. Haroche; Light, vol. 2 (North-Holland, N. Y., 1985), H. Haken, Optical Coherence and Quantum Optics (Cambridge University Press, Cambridge, 1995), L. Mandel and E. Wolf; "From Optical Bistability to Chaos", in Nonlinear Phenomena in Physics, ed F. Claro (Springer-Verlag, N. Y., 1985), H, M. Nussenzveig; Laser Physics (Addison Wesley, Reading, MA, 1974), M. Sargent III, M. O. Scully and W. E. Lamb, Jr; Quantum Optics (Springer, Berlin! 994), D. F. Walls and G. J. Milburn.

NUCLEAR PHYSICS (FIW 710/810)
Topics: Nuclear Forces, Scattering of Electrons and Nuclei by the Nucleus: Nuclear dimensions, optical potential; Liquid Drop Model, Medium Field Models for Spherical Cores and Deformations, Matching Forces, The Core State of the Core: Stability and decay; Collective Nuclear Movement: Vibrations and rotations; Decay of Excited Cores, Heavy Core Collisions; Fusion Reactions relevant to Astrophysics; Transition from the Hadronic Phase to the Quarks and Gluons Phase; Cores outside the Stability Line.
Bibliography: Elements of Nuclei, P. J. Siemes and A. S. Jensen; Nuclear Models, W. Greiner and J. A. Maruhn, Springer, Berlin, 1990.

COLLISION THEORY (FIW 711/811)
Topics: Scattering of a Wave Package, Partial Wave Method: Optical Theorem; Lippman-Schwinger Equation, Born and Distorted Waves Approximation, Eikonal and WKB Approximation, Analytical Properties of Scattering Amplitude, Optical Potential, Formal Scattering Theory: Möller operators, S and T matrices, Coupled Channel Theory, Applications.
Bibliography: Quantum Collision Theory, C. J. Joachaim; Scattering Theory, J. R. Taylor.

ATOMIC AND MOLECULAR PHYSICS (FIW 712/812)
Topics: Electronic States in a Central Field: The non-relativistic case; relativistic corrections; Atoms of Many Electrons: Approximation of central field; Thomas-Fermi model, Self-Consistent Field Models: Hartree and Hartree-Fock methods; The Born-Oppenheimer Model and its Application to Diatomic Molecules, Electronic, Vibrational and Rotational States, Symmetry Groups and Transition Rules in Molecules, Polyatomic Molecules, Intermolecular Forces.
Bibliography: Quantum Theory of Atomic Structure, J. C. Slater; Atomic Structure, E. U. Condon and H. Odabasi; Spectra of Diatomic Molecules, G. Herzberg; Elementary Quantum Chemistry, F. L. Pillar; Physical Chemistry, R, S. Berry, S. S. Rice and J. Ross.

QUANTUM FIELD THEORY I (FIW 713/813)
Topics: Fundamentals of Canonical Quantization and Path Integrals Applied to Fields, Scalar Field: Fermonic Field; Grassmann's variables; gauge fields (abelian case); Faddeev-Popov method; Symmetries and Conservation Laws: Tensor energy-moment; Noether's theorem; discrete symmetries; Interacting Fields: Feynman's Rules, Calculation of Electromagnetic Processes.
Bibliography: Gauge Theory of Elementary Particle Physics, T. P. Cheng and L. F.- Li; Introduction to Gauge Field Theories, M. Chaichian and N. F. Nelipa; Particle Physics and Introduction to Field Theory, T. D. Lee; Quantum Field Theory, L. H. Ryder; Relativistic Quantum Mechanics, J. D. Bjorken and S. D. Drell; Relativistic Quantum Fields, J. D. Bjorken and S. D. Drell; Field Theory: A Modern Primer, P. Ramond.

QUANTUM FIELD THEORY II (FIW 714/814)
Topics: Non-Abelian Fields: Quantization and Feynman's rules, Renormalization: Pauli-Villars and dimensional regularization; Renormalization Group: Applications to QED and QCD; BRST symmetry: Ward identities, Axial Anomaly.
Bibliography: Gauge Theory of Elementary Particle Physics, T. P. Cheng and L. F.-Li; Introduction to Gauge Field Theories, M. Chaichian and N. F. Nelipa; Particle Physics and Introduction to Field Theory, T. D. Lee;

Quantum Field Theory, L. H. Ryder; Relativistic Quantum Mechanics, J. D. Bjorken and S. D. Drell; Relativistic Quantum Fields, J. D. Bjorken and S. D. Drell; Field Theory: A Modern Primer, P. Ramond.

ELEMENTARY PARTICLE PHYSICS (FIW 715/815)

Topics: Fundamental interactions and constituents; leptons and quarks (flavors and colors). Discrete and continuous symmetries; SU (2) and SU (3) groups. Theory of Gauge Fields. Weak interactions; electroweak unification; Standard model. Strong interactions; quantum chromodynamics; asymptotic freedom; lockdown.
Bibliography: Quarks and Leptons, F. Halzen and A D. Martin; Eletroweak Interactions, P. Renton; Gauge Theory of Elements Particle Physics, T. P. Cheng and L. F.-Li; Elementary Particle Physics, O. Nachtmann.

GROUP THEORY APPLIED TO CONDENSED MATTER PHYSICS (FIW 716/816)

Topics: Definitions: Representation theory: irreducible representations, Schur's motto, orthogonality theorem; Characters: characters and classes, orthogonality theorem for characters, character tables; Basic functions: definition, projection operators, examples; Crystalline field splitting: examples; Selection rules; Permutation groups and states of many electrons, Pauli's principle; Molecules, molecular vibrations: infra-red and Raman activity; Tensors: applications in elastic theory and nonlinear optics; Spatial groups, wave vector group and Bloch's theorem; Crystalline vibrations, crystallography, band structure. Spin-orbit interaction in solids and double groups. Symmetry of temporal reversal; Magnetic groups.
Bibliography: Group Theory and Quantum Mechanics, M. Tinkham; Applications of Group Theory to the Physics of Solids, Dresselhaus, (notes); Group Theory and Its Physical Applications, Falicov

CONDENSED MATTER THEORY I (FIW 745/845)

Topics: Electrons in crystals. Dynamics and electron transport. Electronic interactions. Magnetism. Nanostructures and low dimensional systems.
Bibliography: Fundamentals of Condensed Matter Physics, Marvin L Cohen and Steven G Louie; Introduction to Solid-State Theory, Madelung, Otfried; Solid State Physics, N. Mermin and Neil Ashcroft; Condensed Matter Physics, Michael P. Marder.

CONDENSED MATTER THEORY II (FIW 746/846)

Topics: Phonons; Dielectric response; Optical properties; Introduction to many-body techniques; Electron-phonon interaction; Superconductivity.
Bibliography: Fundamentals of Condensed Matter Physics, Marvin L Cohen and Steven G Louie; Introduction to Solid-State Theory, Madelung, Otfried; Solid State Physics, N. Mermin and Neil Ashcroft; Condensed Matter Physics, Michael P. Marder.

MANY-BODY THEORY (FIW 718/818)

Topics: Introduction: the interacting electron gas, Hartree-Fock method, 2nd quantization; Perturbation Theory: Time evolution operator, expansion in propagators, Wick's theorem, Feynman diagrams, self-energy and correlation, RPA; Linear response theory: dielectric function and sum rules, shielding, plasmons; Finite Temperature Theory: Green's functions, perturbation theory; Applications: electron-phonon interaction, superconductivity, superfluidity, etc. (other topics at the discretion of the teacher)
Bibliography: Fetter and Walecka, Quantum Theory of Many-Particle Systems; Negele and Orland, Quantum Many-Particle Systems; Abrikosov et al., Methods of QFT in Statistical Physics; Nozieres and Pines, Quantum Liquids

EXPERIMENTAL METHODS IN CORPUSCULAR PHYSICS (FIW719 / 819)

Topics: Interaction of radiation with matter; Particle production and acceleration; Particle detection; Signal Processing; Data organization, analysis and simulation.
Bibliography: E. Kowalski, Nuclear Eletronics; W. R. Leo, Techniques for Nuclear and Particle Physics Experiments; G. F. Knol, Radiator Detection and Measurement, L. Lyons, Statistics for Nuclear and Particle Physics, R. Lupton, Statistics in Theory and Practice.

TEACHING PRACTICE B (FIW 741/841)

Description: This course aims to provide teaching experience to the graduate students. The students will take classes, preferably of a review or practical nature (exercises or laboratory) at undergraduate level. The weekly workload in the classroom is 1 (one) hour. The activities performed by the student will be supervised by a professor of the undergraduate course. This professor will also be responsible for forwarding his final assessment (along with a report of the work done by the student) to the Graduate Coordinator. The student's grade will be an average of that given by the professor, with that given by the Graduate Council after the analysis of the report. The student will not be responsible for class evaluation.

Courses on advanced topics

Besides the regular courses, described above, the graduate program in Physics at UFRJ offers also, on a regular basis, courses that cover some advanced topics of current interest in the areas of research where we work in. They involve experimental and / or theoretical techniques used in the study of frontier areas in contemporary physics. Each time this discipline is taught, the professor must present a menu, with the bibliography to be adopted, to the Graduate Council for examination and approval.
Bibliography: At the discretion of the professor. Usually the number of such courses offered each semester is about three to four, so that a PhD student will have the opportunity, during his time in the program to choose among many possible courses in different topics

These courses take the names, for the registration procedure in the University, the official names listed below.

TOPICS IN THE PHYSICS OF PARTICLES AND FIELDS A (FIW 720/820)
TOPICS IN THE PHYSICS OF PARTICLES AND FIELDS - B (FIW 721/821)
TOPICS IN ATOMIC, MOLECULAR AND OPTICAL PHYSICS - A (FIW 722/822)
TOPICS IN ATOMIC, MOLECULAR AND OPTICAL PHYSICS - B (FIW 723/823)
TOPICS IN HADRONIC AND NUCLEAR PHYSICS - A (FIW 724/824)
TOPICS OF HADRONIC AND NUCLEAR PHYSICS - B (FIW 725/825)
TOPICS IN CONDENSED MATTER PHYSICS AND STATISTICAL MECHANICS - A (FIW 726/826)
TOPICS IN CONDENSED MATTER PHYSICS AND STATISTICAL MECHANICS - B (FIW 727/827)
TOPICS IN ASTRONOMY, ASTROPHYSICS AND COSMOLOGY - A (FIW 728/828)
TOPICS IN ASTRONOMY, ASTROPHYSICS AND COSMOLOGY- B (FIW 729/829)
TOPICS OF THEORETICAL PHYSICS - A (FIW 738/838)
TOPICS OF THEORETICAL PHYSICS - B (FIW 739/839)