UNIVERSIDADE FEDERAL DE PERNAMBUCO

Course Programs

FIS 725 - Non-Linear Dynamics of Neural Systems
Hours: 75h/semester

Bases of neuronal electrical activity; Conductance-based models; Reduced models; Classification of fixed points; Bifurcations and classes of excitability; Integrators and resonators; Canonical models; Examples of excitability in the brain; Bursting Dynamics; Neural circuits and central pattern generators; Cortical networks with excitation and inhibition.

Bibliography:
Eugene M Izhikevich. Dynamical Systems in Neuroscience The Geometry of Excitability and Bursting. The MIT Press (2006);
Koch, C. and Segev, I. Methods in Neuronal Modeling: From Ions to Networks. MIT Press (1998);
Wulfram Gerstner, Neuronal Dynamics, Cambridge University Press (2014).

FIS 730 - Analysis of Neural Signals
Hours: 75h/semester

Types of neuronal signals and their acquisition: intracellular, extracellular, local field potential (LFP) and electroencephalography (EEG) recordings; Statistics of spike trains; Spike sorting; Brain rhythms and synchronized brain oscillations; Information Theory and applications to Neuroscience; Neural encoding and decoding; Functional connectivity;

Bibliography:
Peter Dayan and L.F. Abbott. Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems (2005). The MIT Press.
Fred Rieke, David Warland, Rob de Ruyter van Stev. Spikes: Exploring the neural code. The MIT Press (1997).
Buzsáki, G. Rhythms of the brain. Oxford University Press (2006).

FIS 765 - Electronic Circuits and Digital Signal Processing
Hours: 75h/semester

Part 1: Basic concepts of electronic circuits. Analog circuits: resistors, capacitors, inductors, diodes, transistors, Op-Amp, feedback, oscillators, comparators, active and passive filters, etc. Special circuits: Lock-in, etc.
Digital circuits: combinational and sequential logic, ADC and DAC conversion, computer architectures, interfacing, FPGA.

Part 2: Digital signal processing. Basic concepts: Linear systems. Electrical signals (continuous, discrete, received from a transducer, etc.),
Measurement and signal processing (time and frequency domains). Amplification vs. Filtering. Statistics, probability and noise. Convolution and Fourier transforms.
Softwares and platforms: C, LabView, MatLab, Python, Arduino, etc.
Practices: Acquisition of signals from a transducer (microphone, thermometer, etc.); ADC conversion; Sampling methods (oscilloscope, spectrum analyzer, sampling plate); Spectral analysis; Filtration, etc.
Note: this syllabus is variable and depends a lot on the class level.

Bibliography:
The Art of Electronics. Horowitz and Hill, 3rd ed. (Cambridge Univ Press, 2015).
LabVIEW: Digital Signal Processing and Digital Communications. Cory L. Clark. (McGraw-Hill, 2005).
Digital Signal Processing: A Practical Guide for Engineers and Scientists. Steven W. Smith. (Newnes, Elsevier Science 2003).

FIS 810 - Computational Methods in Physics
Hours: 75h/semester

Numerical solution of first-order differential equations: simulation of Newton's law of cooling; Numerical solutions of Newton's laws of motion: simulations of movement near the surface of the Earth; Simulations of planetary orbits and verification of Kepler's laws; Mechanical and electrical oscillatory systems: simulations of simple, damped and forced oscillatory movements; Simulations of undulatory phenomena: linear chain of coupled oscillators; Numerical solutions of Laplace's and Poisson's equations: relaxation method; Simulation of gases and liquids: Molecular dynamics; Chaos in dynamical systems; Monte Carlo simulations of random walks in 2D: determination of the diffusion coefficient and applications (self-avoiding random walks, polymers, etc); Percolation and critical phenomena: determination of critical concentrations and critical exponents, finite-size scaling, Monte Carlo method.

Bibliography:
Gould, H., Tobochnik, J. & Christian, W., "An Introduction to Computer Simulation Methods: Applications To Physical Systems", 3rd Edition, Addison-Wesley, 2007.

FIS 812 - Quantum Theory of Many-Particle Systems

Hours: 75h/semester

Quantum Theory of Many-Particle Systems at Finite Temperature; Green's Functions, Wick's Theorem, Dyson's Equation and Perturbation Theory; Non-Perturbative Methods; Thermodynamic Properties and the Zero Temperature Limit; Linear Response and Collective Modes; Selected Topics.

Bibliography: A. Atland and B. Simons, "Condensed Matter Field Theory", Cambridge University Press, Second Edition, 2010. A J.W. Negele e H.Orland , "Quantum Many-Particle Systems", Addison - Wesley, 1988. A. L. Fetter, J. D. Walecka, "Quantum Theory of Many-Particles Systems", McGraw-Hill, Boston, 1971.

FIS 814 - Classical Field Theory
Hours: 75h/semester

Lagrangian Mechanics: Extension to the Continuous Elastic Medium; Lagrangian Formalism for Fields: Scalar Field, Groups and Lie Algebra, Noether's Theorem; Lorentz and Poincaré Groups: Conservation of Total Angular Momentum, Tensor, Energy Momentum; Representations of the Lorentz field: the Klein Cordon and Dirac Fields; Local Gauge Invariance; Electromagnetic Field; Non-Abelian Fields: Yang-Mills Theory; Gravitational Field: Geometric Theory, Einstein's Equations, Schwartzschild's Solution, Gravitational Waves.

Bibliography:
D.E. Soper "Classical Field Theory" , John Wiley & Sons, 1976.

FIS 817 – Introduction to Nonlinear Optics
Hours: 75h/semester

Electromagnetic radiation: Classical and quantum electromagnetic fields; Propagation of paraxial light beams; Optical resonators; Radiation-matter interaction; Interaction of radiation with atomic systems; Coherent interaction of radiation with matter; Maxwell-Bloch equations; Nonlinear optical processes and quantum optics; Second-harmonic generation, Four-wave mixing, Generation of nonclassical radiation, Light with squeezed phase and amplitude, Twin photons.

Bibliography:
A. Yariv, "Quantum Electronics", John Wiley & Sons, 1989.

FIS 818 - Propagation phenomena and Integrated Optics
Hours: 75h/semester

Light propagation in homogeneous media; Optical Cavities: cavity modes, losses, stable and unstable resonances; Light modulation; Electro-optical effects; Amplitude and phase modulation; Electro-optical deflection; Electro-elastic effect; Light deflection by sound; Q-switching and mode-locked lasers; Propagation, modulation and oscillation in dielectric waveguides; Waveguide modes and cross-coupling; Electro-optical modulation; Integrated optics: linear and nonlinear optical pulses; Group and phase velocity; Dispersion and pulse compression; Propagation in nonlinear dispersive media; Nonlinear Schodinger equation; Nonlinear pulse propagation in optical fibers.

Bibliography: R.J. Ebelirog 'Integrabed Optoelectronics" Springer Verdeg Brlin, 1992.

FIS 819 - Atom-Radiation Interaction
Hours: 75h/semester

Hamiltonian of atom-radiation interaction; optically active atomic transitions; temporal dynamics and spectroscopy of few-levels systems; propagation of light in atomic media; mechanical action of light and atomic traps; effects of the quantization of the light field over atomic systems.

Bibliography:
C. Cohen-Tannoudji, J. Dupont-Roc, and G. Grynberg, Atom-Photon Interactions: Basic Processes and Applications, John Wiley & Sons Inc. (1998);
R. Loudon, The Quantum Theory of Light, Oxford Science Publications (2000);
G. Grynberg, A. Aspect, and C. Fabre, Introduction to Quantum Optics, Cambridge University Press (2010);
C. J. Foot, Atomic Physics, Oxford University Press (2005);
M. O. Scully and M. S. Zubairy, Quantum Optics, Cambridge University Press (1997).

FIS 820 - Superfluidity and Superconductivity
Hours: 75h/semester

Superfluidity: Experiments and Phenomenology; Hydrodynamics of Superfluidity; Properties of Elastic Media and Ordinary Fluids;
The Theory of Two Fluids by Tisza and Landau; Second Sound; Thermodynamic Properties of Superfluid Gas and Uniform Condensate; Quasi-Particles; Theories of Landau, Bogoliubov and Feynman; Analogies and Contrasts with Bose-Einstein Transition; Non-Uniform Condensate and Rotating Superfluids: Feynman and Onsager Vortices and Gross-Pitaevky Equation; Critical Properties of Superfluids; Scaling Theories and Renormalization Group; Analogies with X-Y Model; Kosterlitz and Thouless Theory.
Superconductivity: Experiments and Phenomenology; Electrodynamics and Thermodynamics of Superconductors; London-Pippard and Landau-Ginzburg Phenomenological Theories; Meissner effect; Critical Field; Flux Quantization; Microscopic Theory of Superconductivity; BCS Theory and Generalizations; Quasi-Particles; Cooper pairs; Gap Equation and Critical Temperature; Magnetic Properties of
Superconductors: Abrikosov's Vortex State: Interaction between Flux Lines; Superconductivity and High Temperature: Compositions that exhibit superconductivity at high temperatures; Phase diagram; Structural, Magnetic, Optical and Transport Properties; High-Temperature Theories; Critical Properties of Superconductors.

Bibliography:
P.G. Gennes, "Superconductivity of Metals and Alloys", Addison-Wesley, 1986;
D.R.Tilley and J. Tilley, "Superfluidity and Superconductivity", Inst. of Physics Publinding, 1990.

FIS 830 - Atomic and Molecular Physics

Hours: 75h/semester

One-electron Atoms; The Stark Effect; Atomic Polarizability; The Hartree-Fock Method; The Born-Oppenheimer Approximation; Diatomic Molecules; Introduction to Group Theory; Polyatomic Molecules.

Bibliography:

M. Weissbluth, Atoms and Molecules, Academic Press, N.Y., 1978;

B.H. Bransden and C. J. Joachain, Physics of Atoms and Molecules (2nd Edition), Prentice Hall, 2003.

FIS 835 - Fundamentals of Quantum Mechanics and Information

Hours: 75h/semester

Separability, entanglement and other correlations of quantum states.
Characterization and application of quantum entanglement. Generalized measurements, open systems and decoherence. Interpretations of Quantum Mechanics. Elements of the Theory of Quantum Information.

Bibliography:
Quantum Theory: Concepts and Methods, Peres, Kluwer Academic Publishers.
Quantum Information and Quantum Computation, Nielsen & Chuang, Cambridge.
Quantum Processes, Systems and Information, Schumacher & Westmoreland, Cambridge.
Quantum Information, S. M. Barnett, Oxford.
Speakable and Unspeakable in Quantum Mechanics, Bell, Cambridge.
Quantum Mechanics: A Modern Development, Ballentine, World Scientific.

FIS 865 - Quantum Theory of Solids
Hours: 75h/semester

Excitations and interactions in solids; Symmetry properties in solids; Theory of energy bands; Theory of the functional density; Electron-phonon interaction; Transport properties in solids: Magnetic properties of solids; Optical properties of solids; Superconductivity; Nanoscopic physics.

Bibliography:
Quantum Theory of Solids, Charles Kittel. 2nd revised edition (1987) , John Willey and Sons;
A Modern Course in the Quantum Theory of Solids, Fuxiang Han. World Scientific Publishing Co. Pte. Ltd. (2013); A Quantum Approach to Condensed Matter Physics, Philip L. Taylor and Olle Heinonen. Cambridge University Press 2002; Solid State Physics, N. W. Ascroft and N. D. Mermin. Saunders College Publishing, 1976; Condensed Matter in a Nutshell, Gerald D. Mahan. Princeton University Press, 2011.

FIS 875 – Probability theory and stochastic processes
Hours: 75h/semester

The sample space; elements of combinatorial analysis; fluctuations in coin tossing and random walks; conditional probability; the binomial and Poisson distributions; Normal approximation to the binomial distribution; Bernoulli processes; random variables: expectations, variance, covariance, Chebyshev inequality, Kolmogorov inequality, the correlation coefficient; Law of large numbers; branching processes; Chapman-Kolmogorv equation; Markov chain; master equation; the Fokker-Planck equation; stochastic differential equations: the Langevin treatment for the Brownian motion, applications and its relation to the Fokker-Planck equation, the Langevin formulation, Itô-Stratonovich dilemma, non-Gaussian white noise.

Bibliography:
Stochastic processes in physics and chemistry, N. G. Van Kampen, Elsevier (2007);
Handbook of stochastic methods, C. W. Gardiner, Springer (1997);
An introduction to probability theory and its application, W. Feller, John Wiley & Sons (1968).

FIS 890 - Particle physics
Hours: 75h/semester

Introduction to Elementary Particles, Quarks and Symmetries, Hadronic Structure, Partons, Quantum Chromodynamics, Weak Interactions: from Fermi Model to V-A Theory, Gauge Theory, Spontaneous Symmetry Breaking; Higgs Mechanism, Standard Model for Electroweak Interactions, CP Violation and the Cabibbo-Kobayashi-Maskawa, Neutrino Oscillations.

Bibliography:
F. Halzen and A. D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics, John Wiley and Sons, 1984;
D. Griffiths, Introduction to Elementary Particles, Wiley-VCH 2008;
G. C. Branco, L. Lavoura and J. P. Silva, CP Violation, Oxford University Press, 1999;
M. Thomson, Modern Particle Physics, Cambridge University Press, 2013.

FIS 900 – Advanced Mathematical Physics
Hours: 75h/semester

Introduction to differential geometry; Covariant derivatives; Vector fields; Curvature of a connection; Symmetries of a space with metric (Killing vector fields); Einstein's equation; Group theory; Lie groups; Lie algebras; Group representation theory; Spinors and the orthogonal group; Gauge field theory and Yang-Mills field; Use of these mathematical tools in classical field theory; Scalar fields with internal symmetry SO(N); Dirac field in arbitrary dimension; Introduction to superssymetry and supergravity.

Bibliography:
M. Nakahara, Geometry Topology and Physics, Taylor & Francis Group, 2003;
T. Frankel, The geometry of physics, Cambridge University Press, 2004.;
M. Göckeler e T. Schücker, Differential geometry, gauge theories, and gravity, Cambridge University Press, 2004;
A. Zee, Group Theory in a Nutshell for Physicists, Princeton University Press, 2016;
B. D. Freedman e A. Van Proeyen, Supergravity, Cambridge University Press, 2012;
C. L. Castellani, R. D'Auria e P. Fré, Supergravity and superstrings, 1991.

FIS 914 - Quantum Field Theory
Hours: 75h/semester

Classical Description of Fields: Lagrangian Formalism; Path Integral Quantization; Scalar Field; Generating Functional: (Partition Function), Green Function (Correlation Function), Perturbation Theory, Feynman Rules and Feynman Diagrams; Klein-Gordon field; Dirac Field: Grassmann Variables; Gauge Fields; Faddeev-Popov gauge fixing method; Effective action in one-Loop; Non-Abelian Theories; Renormalization.

Bibliography:
C.Itzykson and J.B.Zuber "Quantum Field Theory", McGraw-Hill, 1985.

FIS 916 - Optical Properties of Solids
Hours: 75h/semester

Macroscopic theory of dispersion and absorption of light by solids; Microscopic interaction between radiation and elementary excitations; Spectroscopic techniques; Symmetry properties; Group theory and selection rules; Inelastic scattering: Raman and Brillouin; Introduction to non-linear optical properties.

Bibliography:
O. Madelung "Introduction to Solid State Theory" Springer Verlag, 1981

FIS 917 - Advanced Nonlinear Optics

Hours: 75h/semester

Classical Theory; Nonlinear Polarization; Nonlinear Susceptibilities; Symmetries; Parametric Processes far from Resonances; Quantum Theory of Nonlinear Susceptibilities; Second-Harmonic Generation; Three-Wave Mixing; Optical Parametric Amplifiers and Oscillators; Other Second-Order Effects and Applications; Reflexion and Refraction in Nonlinear Optics; Nonlinear Interferometers; Convolution and Correlation Operations; Third-Order Effects; Kerr Nonlinearity; Nonlinear Raman Spectroscopy; Self-Focusing and Self-Defocusing of Light; Self-Phase Modulation; Solitons; Four-Wave Mixing; Stimulated Light Scattering; Higher-Order Nonlinearities; Non-Perturbative Effects; Optical Bistability, Spatial and Temporal Stabilities.

Bibliography:

Y.R. Shen ”The Principle of Nonlinear Optics" , John Wiley, New York, 1984.

FIS 918 - Quantum Optics
Hours: 75h/semester

Quantization of the radiation field: cavity modes; Some pure states of light: of number, coherent, compressed, etc. and their properties; Mixed states; Interaction of the quantized field with atoms: dipolar approximation; emission and absorption; Jaynes-Cummings model; Dressed atom; The source field; Bloch Equations; Quantum statistics: degrees of coherence; Young experiment; Experiência de Young; Antibunching; Photon counting, homodyne and heterodyne detections; Michelson interferometer; Quantum theory of dumping: density operator method; Langevin method; Atoms as reservoirs; Qhasi-probabilities: Glauber-Sudarshan P function; Wigner function; Q function; Positive P function; Quasi-probabilities for S-Order; Quantum fluctuations and stochastic processes; Generation and amplification of light: Lasers; Micromaser; Parametric Amplifiers and Oscillators; Resonance Fluorescence; Superradiance - Dicke model.

Bibliography:
L. Mandel and E. Wolf, "Optical Cohferences and Quantum Optics" Cambridge Univ. Press, Cambridge, 1995.

FIS 920 - Magnetic Properties of Materials
Hours: 75h/semester

Phenomenological Aspects of Magnetic Systems; Microscopic Origins of the Magnetic Interactions; The Magnetic Hamiltonian; Paramagnetism; Diamagnetism; Ferromagnetism and Magnetic Systems of Complex Structures; Magnetic Excitations; Magnetism of Insulators, Semiconductors and Metals; Magnetism of Disordered Systems; Experimental Techniques- Magnetic Resonance, Magnetometry, Magneto-Optical Measurements.

Bibliography:
A.P.Guimarães "Introduction to Magnetism and Magnetic Resonance in Solids" John Wiley, 1998

FIS 924 - Field Theory Methods in Statistical Physics and Condensed Matter
Hours: 75h/semester

Part 1: Path integrals: Applications in Quantum Mechanics, Statistical Mechanics and Field Theory; Fundamental Concepts and Ideas in the Theory of Critical Phenomena: Characterization, Critical Exponents, Scaling Theory, Universality Models; The f4 Field Theory: Generating Functional of Green and Vertex Functions, Diagrammatic Structure and Calculation Rules; Renormalization of f4 Theory: Heuristic Aspects, Renormalization Conditions, Relevant and Irrelevant Operators, The Renormalization Group and scaling theory in the Critical Region; Calculation of Critical Indices in the f4 Theory: Expansion in e = dc-d Dimensions; Conformal Invariance and Critical Phenomena in Low Dimensional Systems.
Part 2: Fundamental aspects of Fermionic systems; Grassmann variables; Strongly correlated systems; Hubbard Model and generalizations; Quantum Magnetism, Bethe's Ansatz, Non-Linear Sigma Model and Topological Effects; Quantum Hall Effect, Anyon Superconductivity, Flux quantization and Chern-Simons gauge theory; Theories of High Temperature Superconductivity.

Bibliography:
D. Amit, "Field Theory, the Renormalization Groups, and Critical Phenomena", World Scientific, 1989;
E. Fradkin, "Field Theories of Condensed Matter Systems", Addison-Wesley.

FIS 932 - Polymeric Nanostructures
Hours: 75h/semester

Non-conventional polymers: basic concepts, preparation, properties and characterization; nanocomposites and polymeric membranes; Characterization techniques: Impedance, UV-visible, fluorescence and infrared spectroscopies; Proteins and nucleic acids: Structure and Function; Protein folding; DNA and RNA; Biotechnology methods; Applications: conformational changes in proteins; Separation of biomolecules, rapid diagnostic tests, remediation of aqueous media.

Bibliography:
T. A. Skotheim and J. R. Reynolds, Handbook of conducting polymers. Conjugated polymers: theory, synthesis, properties, and characterization (CRC Press, Boca Raton, 2007);
B. Valeur, Molecular fluorescence: principles and applications (Wiley-VCH: Weinheim, New York, 2002);
K. Sneppen, G. Zocchi, Physics in molecular biology, Cambridge University Press, Cambridge, UK; New York, 2005;
A.V. Finkelstein, O.B. Pti͡tsyn, Protein physics: a course of lectures, Academic Press, Amsterdam; Boston, 2002; J.M. Walker, R. Rapley, Molecular biology and biotechnology, 5th ed., Royal Society of Chemistry, Cambridge, 2009;
N. P. Cheremisinoff, Groundwater remediation: a practical guide for environmental engineers and scientists. Hoboken, NJ, USA, John Wiley & Sons Scrivener Publishing LLC (2017).

FIS 935 - Thermal and Transport Structural Properties
Hours: 75h/semester

Structural Phase Transitions; Material Production Techniques: Solid State Reaction, Crystallization of Solutions, Transport in the Vapor Phase, Electrochemical Methods, Preparation of Thin Films, Monocrystal Growth; Material Characterization: X-Ray Diffraction, Electron Diffraction, UV-VIS-IV Spectroscopy, Neutron Diffraction, Optical Macroscopy and Electronics, Thermal Analysis (DTA, TGA, DSC and Specific Heat), Thermal Conductivity, Thermoelectric Effects, Optical Properties, Electrical Resistivity, Thermal And Magnetic Noises , Magnetoresistance and Hall Effect; Elementary Excitations in Crystalline Solids, Amorphous and Quasi-Crystals: Electrons and Holes, Tunneling States, Phonons, Fractons, Polarons, Magnons and Localized States; The Non-Metal Metal Transition: Mott-Insulators Hubbard, Hubbard Hamiltonian, Mott's Transition in Transition Metal Oxides, Conductive Polymers and Quasi-Crystals.

Bibliography:
Anthony R. West, "Solid State Chemstry and its Applications," John Wiley &Sons, 1984

FIS 940 - Phase Transitions and Critical Phenomena

Hours: 75h/semester

Phase Diagrams and Phenomenology. Thermodynamic Description of Phase Transitions: Thermodynamic Potentials and Response Functions, Phase Coexistence, Critical and Multicritical Points, Clausius-Clapeyron Equation, Van der Waals Theory, Critical Exponents; Statistical Mechanics of Phase Transitions: Yang & Lee Theorem, Fluctuations and Correlations; Landau Theory and Fluctuation Effects: Order Parameter, Spontaneous Symmetry Breaking, Ginzburg Criterion, Critical Dimension, Critical and Multicritical Points; Scaling Theory and Universality Classes; Exactly Soluble Models; Renormalization Group Method; Conformal Invariance and Critical Phenomena in low-dimensional Systems.

Bibliography:

J.J. Binney, N.J.Dowick, A.J. Fisher, and M. E. Newman, "The Theory of Critical Phenomena", Clarendon Press, Oxford, 1993.

H.E. Stanley, "Introduction to Phase Transitions and Critical Phenomena", Clarendon Press, 1971.

FIS 910 – Physics of Complex Systems

Credit hours: 75/semester

Complexity in the Physical World: Historical Introduction, Concepts and Indicators, Scaling Laws, Fractals and Multifractals; Applications, and Chemical and Biological Systems; Fractal Dynamics, Excitation and Relaxation in Fractals; Random Walks and Transport Phenomena; Percolation; Cellular Automata as a Model for Complexity; Growth Models: Aggregation, Coagulation, Deposition, Fractures, Consuption and Fragmentation; Phenomenology; Mean Field Arguments: Rate Equations, Scaling Phenomenological Schemes; Numerical Simulations; Theoretical Schemes; Renormalization Group; Fixed Scale Transformation; Neural Networks and Spin Glasses; Optimization Phenomena.

Bibliography:

J. Felder "Fractals" Plenum Press, 1988.

E. Ott "Chaos in Dynamical Systems", Cambridge Univ. Press., 1993

FIS 815 – Non-Equilibrium Statistical Mechanics
Hours: 75h/semester

Kinetic Theory, Relaxation and Fluctuation; Linear Response e Hydrodynamics; Symmetry Breaking; Master Equation and the Fokker-Planck Equation; Langevin and Glauber Dynamics; Critical Dynamics.

Bibliography:
R.Kubo, M. Toda e T.C. Lubensky , "Statistical Physics II" , Springer Verlag 2nd, 1985.

FIS 785: Special Topics I, FIS 786: Special Topics II, FIS 945: Special Topics D1, FIS 946: Special Topics D2
Hours: 45h/semester

Variable programs whose content depend on the research interests of instructors and students. These courses aim to improve the students skills in their research fields, typically addressing topics which do not appear in regular courses.

Bibliography:

To be indicated by the instructor.