COURSE DESCRIPTION

Below is a description of the courses, which, are classified according to the code of each course.

9003 INTRODUCTION TO PROGRAMMING

1st semester
Core Prog.

Introduction to Computer Science. *Simple algorithms and data structures.* Programs and programming languages. Integrated program development environments. *Introduction to object oriented programming in Java.* Objects, classes and methods. Implementation methods. Data types and operators. Parameter passing. Selection and flow control instructions. *Introduction to the Application Programming Interface* (API, basic java libraries). Strings, arrays, linked lists. Recursion. Debugging. **Lab**: Series of supervised lab exercises in Java. Use of dedicated to teaching integrated programming environment (BlueJ).

Object oriented programming in Java. Inheritance and polymorphism. Abstract classes and interfaces. Exceptions. Data input and output. Data collection classes. Graphical user interfaces. Applets. *Design of object oriented programs. Analysis of simple algorithms and data structures.*

Lab: Series of supervised lab exercises in Java. Use of dedicated to teaching integrated programming environment (BlueJ).

9007 INTRODUCTION TO PHILOSOPHY

3rd semester
Core Prog.

The Historic and Systematic Approach to Philosophy. Problems and Periods of Western Philosophy. Systematic presentation and analysis of central issues in Philosophy: the validity of knowledge, truth, mind and matter, language and the real world, the significance of Philosophy today.

9024 PHILOSOPHY OF SCIENCES

4TH SEMESTER
CORE PROGR.

The (perennial) problem of the Rupture with our (recent or remote) epistemological past. The distinction of truths into necessary and contingent (Leibniz). The employment of the distinction by Hume in his criticism of causality. Kant’s concept of synthetic a priori. Rupture as a conflict with truths of reason (necessary). The contextualist account of Analyticity. The refutation of Quine. Incommensurability as the conflict with a topical truth. The philosophy of J. L. Austin. The Darwinian view of language. Locution. Illocution and Perlocution. The suppression of Rupture.

9032 PROBABILITY

5TH SEMESTER

The notion of probability. Axioms of probability. Probabilistic spaces, Combinatorial Analysis. Conditional probability and independent events. Theorem of total probability and Bayes’ rule.

Random variables. Density function. Special density functions (Binomial, Negative Binomial, Geometric, Hypergeometric, Poisson, Uniform, Normal, Exponential, Gamma, Lognormal, Weibull, Chi-Square, Student's t, Snedecor's F). Multivariate distributions (Multinomial, Multivariate Normal). Expected value, variance and covariance. Conditional expectation. Distributions of functions of random variables. Convolution. Probability and moment generating functions. Characteristic functions. Convergence of sequences of random variables. Laws of large numbers. Central limit theorems and applications.

9033 PHYSICS – III (OSCILLATIONS AND WAVES) INCLUDING LABORATORY

3RD SEMESTER
CORE PROGR.

The harmonic oscillator (undamped and damped). Forced oscillations. Resonance. Coupled oscillators, normal modes of vibration, system with many degrees of freedom. Electric oscillations. Waves in 1-dimension continuous media Phase and group velocity, dispersion. Reflection, transmission at a discontinuity. Fourier methods, band-width theorems. Waves in 2-dimensions. Waves in 3-dimensions. Electromagnetic Waves, Interference. Diffraction.

9041 NUMERICAL ANALYSIS I AND LABORATORY

3RD SEMESTER
CORE PROGR.

Introduction to Fortran, Matlab and Mathematica**. An Introduction to Rounding Errors:** Numbers Arithmetic Representation, Basic Rounding Errors. **Linear Systems:** Gauss Elimination Method, LUandCholeski Factorization Methods. Norms (Vector, Matrix, Function).Stability of Linear Systems.Fixed Point Iteration Schemes.Jacobi, Gauss-Seidel and Relaxation Methods.Least Squares Methods and Applications.Numerical Computation of Eigenvalues/Eigenvectors.**Nonlinear Equations:** Bisection Method**.** Fixed Point Iteration Methods, Newton-Raphson (for Equations and Systems).**Interpolation and Approximation:** Lagrange Interpolation.Newton Polynomial**.**Hermite Interpolation**.**Cubic Splines**.**Best Approximation via Least Squares**.** Orthogonal Polynomials**.Numerical Integration:** Newton-CotesRules (Trapezoidal, Simpson, 3/8). Gauss Integration**.Introduction to ODEs:** Euler, Taylor and Runge-Kutta Methods.

9056 INTRODUCTION TO CONTINUUM MECHANICS

5TH- SEMESTER

The Basic Hypothesis in Continuum Mechanics. Kinematical Description (Material and Spatial Descriptions). Displacement Gradient. Material Derivative. Reynolds Transport Theorem. Balance Laws (Mass, Momentum, Energy). Introduction to Fluid Mechanics. Incompressible Fluids. Inviscid Fluids. Equations of Continuity. Bernoulli's Equation. Constitutive Equations for Solids and Fluids. Simple Problems of Motion and Deformation of Solids. Simple Problems of Motion and Deformation of Fluids. Introduction to Partial Differential Equations of the 1st Order and the 2nd Order. Waves in Solids. Waves in Fluids. Navier-Stokes Equations. Prandtl's Boundary Layer Theory.

9058 ALGEBRA AND APPLICATIONS

7TH- SEMESTER

Partitions and equivalence relations. Introduction to Group Theory. Groups of symmetries, the dihedral groups. Cyclic groups: the nth roots of unity, remainder classes, the integers, the classification of cyclic groups. The Theorems of Fermat and Euler, linear congruences. Permutation groups, Cayley's theorem. Cosets (application to linear codes), Lagrange' theorem, normal subgroups, quotient groups. Free groups, free abelian groups, group presentations. The classification of finitely generated abelian groups. The abelianizer of a group. Introduction to rings, integral domains and fields.

This course is particularly useful to those who have selected the stream «Mathematics for Information Sciences».

7TH- SEMESTER

9068 COMPUTATIONAL PHYSICS – I

Introduction: Operating system, programming language. Programming techniques, compiling, linking, optimization. Electrostatics: Field and equipotential lines of the electric field of a planar distribution of point charges. Solution of Laplace and Poisson equation on the plane. Particle dynamics in 1 dimension: Integration methods of initial value problem, Euler and Runge-Kutta methods. Data analysis, plotting. Study of convergence and systematic errors. Applications: Harmonic oscillator with damping and external force. Simple pendulum with damping and external force and study of its chaotic behaviour. Particle dynamics in 2 dimensions: Motion in the gravitational field, friction. Planetary motion. Scattering. Particle Dynamics in 3 dimensions: Adaptive Runge-Kutta methods. Interface with third party code. Particle motion in space under newtonian and special relativistic dynamics. Motion of ultrarelativistic particles in the dipole magnetic field.

7TH- SEMESTER

9071 PHILOSOPHY OF PHYSICS

Foundations of spacetime theories, symmetry principles and covariance (Newtonian physics, special and general relativity). Conventionality of geometry. Conventionality of simultaneity. Causal theories. Substantivalism and relationism (the Newton-Leibniz debate, the hole argument). Foundations of quantum theories. Uncertainty principles and early attempts at interpreting quantum mechanics (Einstein, Heisenberg, Bohr). The EPR argument. Bell inequalities, locality and separability. The problem of quantum measurement. The doctrine of determinism. Determinism in physics (Newtonian mechanics and gravitation, classical field theories, special and general relativity, quantum mechanics).

6TH- SEMESTER

9074 CONDENSED MATTER PHYSICS

Free electron model (Thermal equilibrium and transport properties). Crystal lattices. X-Ray Diffraction from crystals. The reciprocal lattice. Crystal bonding (Classification of crystal lattices). Motion of electrons in a periodic potential. Bloch theorem. Energy bands. Semiconductors. Effective mass. Density of states. Fermi level in intrinsic and extrinsic semiconductors. Lattice vibrations. Thermal properties. Surfaces. Amorphous solids.

The course includes laboratory exercises

7TH- SEMESTER

9078 FUNCTIONAL ANALYSIS I.

◆*Elements of Linear Algebra*: vector spaces, linear operators, convex sets. *Norms in vector spaces*: The fundamental definitions, balls in normed spaces. The interrelation b etween algebraic and topological structure of normed spaces. Banach spaces. ◆*Continuous or bounded operators*: basic properties, the norm in the space B(X,Y), the space X* of linear functionals defined on X, isomorphisms and isometries between normed spaces, the subsequent continuity of linear operators in finite dimensional spaces. ◆*Hilbert spaces*: Inner product, the dual space of a Hilbert space, orthonormal systems. ◆*Hahn-Banach Theorem*: The consequences of the theorem, the natural imbedding of X into X**, the dual spaces of L_p. ◆ *The geometrical form of Hahn-Banach Theorem*: The Minkowski functional, the Hahn-Banach separation Theorems, the theorem of Krein-Milman. Applications of Baire's theorem in Banach spaces. The Uniform boundedness principle, the open mapping theorem, the closed graph theorem. Quotient spaces.

9081 MATHEMATICAL ECONOMICS

7TH- SEMESTER

Preference relations and utility functions: Continuity, convexity of preference relations and utility functions. Upper and lower semicontinuous functions on metric spaces. Maximization on convex sets, representation of preference relations. Demand theory: Budget set, demand correspondence. Multivalued functions on metric spaces. Continuity. Exchange Economies: excess demand function and equilibrium. Allocations (Individually rational, Pareto optimal, core allocation, equilibrium allocation). Productions Economies: Productions sets, linear optimization. Equilibrium theory: Fixed point theorems, Equilibrium theorems.

9095 OPTICS AND OPTICS LABORATORY

5TH- SEMESTER

Introduction to wave optics. Polarization of light. Reflection, refraction at plane and curved surfaces. Mirrors, lenses, prorerties and errors. Optical instruments (the eye, magnifyinng lens, microscope and telescope).Space and time coherence. Interference and diffraction. Optical Fourier transformations, space filters, holography. ◆ **Laboratory:** Six laboratory exercises: **1.** Interference and diffraction, slits – diffraction gratings, delay plates. **2.** Optical Fourier transformations. **3.** Interferometry (Michelson, Fabry – Perot). **4.** Laser modulation, Optical information transfer. **5.** Holography. **6.** Boundary conditions and Fresnel relation for s and p polarization.

9099 MATERIAL CHARACTERIZATION METHODS

6TH- SEMESTER

This is a purely laboratory course of 4 hours per week, where the presentation of the experimental method and experimental setup is preceding (1.5 hours), while the realization of the experiment and the data collection will follow (2.5 hours). The session closes with discussion and suggestions for analyzing the results. For each exercise, each student delivers a full report, no later than one week after the completion of the exercise. EXERCISES: 1) Differential Scanning Calorimetry, 2) Dielectric spectroscopy, 3) Raman spectroscopy, 4) IR spectroscopy, 5) Atomic Force Microscopy, 6) Electrical measurements in semiconducting systems, 7) Nuclear Magnetic Resonance, 8) Scanning Electron Microscopy, 9) Magnetic measurements, 10) Photovoltaic cell study.

9106 SOFTWARE FOR PHYSICS, MATHEMATICS AND THEIR TEACHING

2ND SEMESTER
CORE PROGR.

Introduction to Mathematica: Basics, Functions with variable arguments, Basic symbolic computations, **Lists.** Matices, Arrays, Relational and logical operators, *Graphics in Mathematica,* Algebraic Computations, *Applications of Mathematica in mathematical problems:* Numerical solutions of nonlinear equations, systems, differential equations, system of differential equations, interpolation and optimization problems. Applications of Mathematica in Physical Sciences. *Introduction to Matlab:* Basics, Functions with variable arguments lists, Mathematical functions, Matrices, matrix generation, matrix and array operations, matrix manipulation, Operators, relational and logical operators, M-files, scripts and functions, inline function, editing M-files, Graphics, two-dimensional graphics, Basic plots, multiple plots in a figure, three-dimensional graphics, Applications of Matlab in mathematical problems, *Symbolic computations with Matlab.*

9110 DIELECTRIC, OPTICAL, AND MAGNETIC PROPERTIES OF MATERIALS

7TH SEMESTER

Dielectric and Optical Properties of Insulators: Static fields: Local electric field. Polarizability. Dielectric constant. Alternating fields: Optical absorption. Polariton. Piezoelectricity. Ferroelectricity. ◆ *Magnetic Properties of Matter:* Diamagnetism. Paramagnetism. Ferromagnetism. Antiferromagnetism and Ferrimagnetism. ◆ *Magnetic Resonance Phenomena:* Electronic magnetic resonance. Relaxation mechanisms. Bloch equations for the steady state. Nuclear magnetic resonance. ◆ *Superconductivity*

9114 REGRESSION ANALYSIS

7TH SEMESTER

Introduction to the linear model. Multiple linear regression. Model parameter estimation. Properties of estimators. t and F tests of hypotheses, coefficient of determination R2, confidence intervals for parameters. Residuals, diagnostic tests. Prediction. Multicollinearity, heteroscedasticity and other problems. Transformations. Weighted least squares. Model selection methods. Influence. Cook’s distance. Dummy variables. Analysis of variance and its relation to the general linear model. Poisson regression. Logistic regression. Practical sessions using statistical software packages.

9116 ALGORITHMS AND COMPLEXITY

7TH SEMESTER

Techniques for asymptotic program analysis and algorithm selection criteria. Algorithm design techniques: divide and conquer, dynamic programming, greedy algorithms. Applications to graph theory (depth-first search, breadth-first search, minimum spanning tree, shortest path). Sorting and searching. Algebraic problems (evaluation of polynomials, matrix multiplication). Polynomial-time algorithms and NP-complete problems.

9118 GRAPH THEORY

8TH SEMESTER

Introduction: Definitions, Subgraphs, Connected graphs, Trees, Networks, The connector problem. *Euler and Hamilton Graphs. Necessary and sufficient condition for Euler graphs.* Fleury’s algorithm. Hamiltonian graphs: Necessary conditions. Sufficient conditions. Planar graphs. Euler’s formula. Kuratowski’s theorem. Dual graphs. *Vertex colourings.* The Welsh Powell algorithm. The five and four colour theorems. Brook’s theorem. Edge colourings. Vizing’s theorem. *Connectivity.* Connectivity. Menger’s theorem vertex and edge form. Max-flow, min cut. *Matchings:* Hall’s marriage theorem. Matchings in bipartite graphs. The personnel assignement problem. Stable marriages. *Matrices.* The adjacency and incidence matrix. The matrix tree theorem.

9120 **INTRODUCTION TO OPERATIONAL RESEARCH** 7TH SEMESTER

Operational Research approach to modeling. Formulation of OR problems and case studies. Analysis of Linear Programming models. Graphical modeling and solution. Simplex Method. Solution by using computer packages. Slack variables. Duality theory. Interpretation of Duality. Sensitivity Analysis. Transportation Problem. Project evaluation and management with or without limited resources. Integer programming. Decision making under uncertainty. Decision criteria. Decision trees. Inventory control and management. Economic order quantity and reorder point with or without uncertain demand. Queuing Theory. Dynamics of a queuing system with interarrival time and service time coming from any probability distribution, for a single or multiple servers.

9123 **STATISTICAL PHYSICS** 5TH SEMESTER

The microcanonical ensemble. The canonical ensemble. Partition function. Connection with thermodynamic quantities. Parmagnetism. The grand canonical ensemble. Fermi – Dirac and Bose – Einstein distributions. Black – body radiation. Real gases. Phase transitions.

9125 **APPLICATIONS OF IONAZING RADIATION IN MEDICINE AND BIOLOGY** 8TH SEMESTER

Note: The course includes laboratory exercises and visits to hospitals and to NRC “Demokritos”

Principles of the Physics of ionizing radiation. Ionizing radiation characteristics as properties of the atomic nucleus. Theory of the interaction of ionizing radiation with matter.Nuclear reactions and isotope production. Clinical application of radioisotopes and radiopharmaceuticals. Detector instrumentation for the three fundamental types of radiation, α, β, and γ. Ionizing radiation effects on biological organisms. Biological effect of neutrons and their use in clinical medicine. Advanced techniques for clinical applications and the use of accelerating apparatus. Introduction to dosimetry and radiation protection.

9136 **PHILOSOPHY OF MATHEMATICS** 7TH SEMESTER

Introduction: necessity and a priori nature of mathematics, existence and ontological status of mathematical entities (realism, idealism, nominalism), mathematical truth. Plato and Platonism in mathematics. Aristotle’s philosophy of mathematics. The philosophy of mathematics in rationalism and empiricism (Descartes, Leibniz, Locke, Berkeley, Hume). Kant’s philosophy of mathematics. Mill’s philosophy of mathematics. Elements of formal logic. Set-theoretic and semantic paradoxes. Elements of axiomatic set theory. The main schools in early 20th century philosophy of mathematics: Logicism, Formalism, Intuitionism. Logical Positivism. Structuralism. Other contemporary views.

9153 **COMPOSITE MATERIALS** 9TH SEMESTER

1. Introduction classification of materials. Ductile and fragile materials. Isotropic and non isotropic materials. **2**. Composite materials. History and development. Uses and applications. Advantages and disadvantages when compared with other structural materials. Main fabrication methods. **3**.

Inclusions in composite materials. Particles, fibres and flakes. Characteristics and thermomechanical properties. Types of inclusions. Glass, carbon, aramid, graphite, boron fibres. Advantages and disadvantages. **4**. Matrix materials. Polymeric, metal and ceramic matrices. Thermosetting and thermoplastic polymeric matrices. Thermomechanical properties of matrices. Advantages and disadvantages. **5**. Phases in composite materials. Filler volume fraction and weight fraction. Voids, microcracks, microdefects in composites. Particle and fibre distribution in composite materials. Planar and special models. Applications. **6**. Theoretical predictions of thermomechanical properties of particulate composites. Semi – empirical formulae in the literature. Formulae based on mechanics of material approach. Derivation of the formulae based on theory of elasticity. Applications. **7**. Unidirectional fibre reinforced composites. Transversely isotropic, orthotropic, monoclinic fibrous composites. Random fibre reinforced composite materials. Laminates. **8**. Stress – strain relationships in various types of fibrous composites. Stiffness matrix and compliance matrix. Mathematical constants and engineering constants in principal material directions. Applications. **9**. Stress – Strain relations in off – axis composites. Stiffness and compliance matrices. Elastic constants. Applications. **10**. Failure criteria in fibre reinforced composites. Max stress criterium. Max strain criterium. Tsai – Hill criterium. Advantages / disadvantages. Applications. **11**. Laminates. Cross – ply, angle – ply laminates. Force and moments. **12**. Non destructive tests in composite materials. Practical applications of composites. Patches and repairs in composites.

9157 TEACHING METHODOLOGY PRINCIPLES - TEACHING OF MATHEMATICS

6TH SEMESTER

Basic concepts of teaching. Psychological considerations for learning and teaching in mathematics. The role of representation in mathematics. Semiotic representation systems and their importance in the learning process. The natural language in mathematics. The teaching contract. The socio-cultural approach to research methodology and the influence of cultural context to the understanding of mathematical concepts.

9159 NUCLEAR PHYSICS AND APPLICATIONS

8TH SEMESTER

Nuclear reactions – cross section. Nuclear decay law. Bound states of nucleons – deuterium – nucleon exchange forces. Nuclear models (liquid drop, shell, collective). Nuclear deformation Electric and magnetic multipoles. γ ray emission. Nuclear magnetic resonance. Rutherford scattering. Nuclear reactions. Applications of Nuclear Physics in the study of materials (RBS, ERDA, PIXE, etc.), in medicine (diagnosis – therapy), to the environment, in archaeometry, in industry

The course includes laboratory exercises

9165 BIOPHYSICS

6TH SEMESTER

Forces – interactions between biomolecules. Water and its role in the structure of living matter. Biopolymers (structure, function and physical properties). Physical methods for the study of macromolecules and cells. Membranes and transport properties of biological membranes. Generation and propagation of the nerve pulse. Bioelectric potential recording techniques. Muscle contraction, bio-thermodynamics, bioenergetics. Biophysics of vision and hearing. Effects of physical factors in living matter. ◆ *Laboratory exercises:* Spectrometry: absorption spectra of biopolymers, correlation of optical properties with the structure and behavior of macromolecules under various conditions (radiation, active substances). Amplification – recording of bioelectric signals.

Note: The course includes laboratory exercises

9171 TEACHING METHODOLOGY PRINCIPLES - TEACHING OF PHYSICS

6th SEMESTER

Scientific Literature - Learning Theories – Students' Alternative Conceptions in Physics - Models for Teaching Science – Science Processes - Inquiry Based Learning - Instructional Tools – The Use of Information and Communication Technologies in Physics Teaching – The Use of Informal Sources of Science Learning in Teaching – The Designing of Physics Lesson Plans (Teaching Aims – Student Worksheets – Lesson Assessment)

9172 PEDAGOGICAL PRINCIPLES

5TH SEMESTER

The aim of this course is the theoretical training of students to basic principles of Pedagogy and General Education. During the course, learning theories are developed based on the respective instructional models. There is particular emphasis given on modern learning theories, for example, the theory of knowledge edification. Development of teaching models and attempts for a comparative approach between them based on their features such as the nature of knowledge and others. The basic components of the course are: a) Theories of learning (associative learning-classical theory, instrumental-associative learning theory, social-cognitive learning theory, logical-mathematical learning theory of Piaget, discovery learning theory of Bruner, learning theory of Ausubel, learning theory of Vygotsky), b) learning model (behaviorism, social behaviorism ¬ lish the scientific, Gnosticism / structuralism, constructivism), c) Course development. Innovations in Education, d) Use of ICT and Modern Teaching, e) Applied pedagogy. Laboratory applications and field applications. In addition to the course the students can take the optional writing of a coursework on a theme appropriate to their interests.

9198 APPLICATIONS OF LASERS IN BIOMEDICINE AND ENVIRONMENT

9TH SEMESTER

Basic principles of the interaction of laser radiation with living matter. Biophysical action mechanisms. Diagnostic applications of lasers. Surgical applications of lasers. Photodynamic therapy. Medical lasers and dosimetry. Laser safety. Basic principles of the propagation of laser radiation in the atmosphere. Mie and Rayleigh scattering. Raman scattering. LIF technique. LIDAR technique (radiation propagation equation, set-up geometry, signal recording techniques). DIAL technique.Measurement of pollutants in the atmosphere and the hydrosphere.

9200 NEW TECHNOLOGICAL MATERIALS

9TH SEMESTER

Introduction. Ceramics, physical properties and preparation methods. Dielectric, Semiconducting, Superconducting ceramics, Ionic ceramic conductors, Amorphous ceramics, Glasses, Nano- and porous-ceramics, Advanced ceramic materials. Dielectrics, insulating materials, dielectric materials for capasitors, microelectronic dielectrics. Active dielectric materials, Ferroelectric, Piezoelectric and Pyroelectric materials, Electretes. Photovoltaic materials. Solid State electrolytes. Liquid crystals.

9TH SEMESTER

9201 MICROSYSTEMS AND NANOTECHNOLOGY

Microsystems and nanosystems: Definitions and examples. Relationship between microelectronic, micro-optical and micro-electro-mechanical technology. Basic microelectronic technology processes and modeling: Thermal oxidation, dopant diffusion, ion implantation, physical and chemical deposition, lithography, etching. Examples of microelectronic device fabrication. ◆ Special processes for micromechanics and microsensor fabrication. Surface and bulk micromachining. Physical principles of sensors operation. Examples on fabrication and operation of physical and biochemical microsensors. ◆ From microtechnology to nanotechnology: Methods of fabrication at the nanoscale. Fabrication of nanoparticles and naowires, their interaction with the macro-world. Applications to nanoelectronics and microsensors.

8TH SEMESTER

9203 COMPUTATIONAL PHYSICS II

Introduction: Statistical Physics: Canonical Ensemble, Partition function, expectation values, free energy and entropy, density of states, fluctuations. 2 dimensional Ising model. Phase transitions, correlation length, universality. Basic Principles of Monte Carlo Simulations: Sampling, importance sampling, Markov chains, detailed balance condition, acceptance ratios. Random Walks: Random walks in two dimensions. Programming language and techniques. Random number generators. Simulations of random walk models. Data analysis: expectation values, statistical errors. Study of geometrical properties of random walks. Simulations of 2d Ising model, part I: Metropolis algorithm. Code design, modular programming, optimization, using scripts for automation. Data structure. Thermalization, autocorrelation times, times series analysis. Error calculation using binning, jackknife and bootstrap methods. Simulations of 2d Ising model, part II: Critical slowing down, cluster algorithms. Finite size scaling, calculation of critical exponents. Potts models in 2 dimensions: Cluster and heat bath algorithms. Phase transitions in Potts models. First order phase transitions.

9TH SEMESTER

9204 PATTERN RECOGNITION AND NEURAL NETWORKS

Review of linear algebra, linera transformation & probability theory, conditional probability and Bayes rule; Introduction to statistical pattern recognition, feature detection, classification; Bayesian decision theory of pattern recognition; Linear and quadratic discriminant functions; Parametric estimation and supervised learning; Theory of Perceptron; Parzen, K-Near Neighbor (K-NN) classification methods ; Dimensionality reduction, Fisher & entropy techniques; Unsupervised learning, clustering K-means; Neural networks for pattern recognition; Learning

9TH SEMESTER

9205 ENVIRONMENTAL PHYSICS

Atmosphere and biosphere structure and composition. Propagation of radiation and equations of motion in the atmosphere. The ozone layer and the ultraviolet radiation. Stability conditions in the atmosphere. Planetary Boundary Layer. Air pollution. Hydrosphere structure and composition. Propagation of radiation and equations of motion in the hydrosphere. Water pollution. Energy exchange mechanisms between the atmosphere and the hydrosphere. Worldwide climatic change.

The course includes laboratory exercises.

6^{O} SEMESTER

9214 DATA STRUCTURES

Abstract data types and their implementations. Lists, stacks, FIFO queues, priority queues, symbol tables, disjoint sets, graphs. Implementations based on search trees (binary trees, AVL trees, splay trees, B-trees, red-black trees), heaps (binary, binomial, Fibonacci) and hashing. Sorting algorithms. Applications.

7TH SEMESTER

9307 INTRODUCTION TO BIOMECHANICS

Introduction: Scope. Historic review. Elements of anatomy. Elements from the theory of elasticity. Anisotropy. *Bone tissue*: Composition and structure. Bone tissue under various mechanical loads. Influence of muscles on the mechanical behaviour of bones. Fatigue. Bone remodeling. Degeneration of bone tissue due to ageing. Case studies. *Fracture and failure*: Failure crtiteria. *Biomechanics of articular cartilage*: Composition and structure. Articular cartilage under mechanical loading. Lubricating role of the articular cartilage. *Spine biomechanics*: Structure and geometry of the vertebrae. *Clinical application*: Spine implants. *Elements of viscoelasticity and poroelasticity. The intervertebral disc. Elements of hyperelasticity. Biomechanics of ligaments:* Structure and composition. Biomechanical function of the ligaments. *Application: Anterior Cruciate Ligament (ACL)* - Numerical simulation of the mechanical behaviour of ACL. *Tendon biomechanics*: Structure and composition. Biomechanical function of the tendons. *Application: The Achilles tendon* – Influence of training and dopping on the Achilles tendon. *Biomechanics of Joints:* Kinematics and kinetics of joints. The knee joint. *Foot Biomechanics. Introduction to Gait Analysis.*

Laboratory tests: Three point bending of rats femurs. Tension of soft tissues. Pull-out tests with pedicle screws.

7TH SEMESTER

9308 DYNAMICAL SYSTEMS AND OSCILLATIONS

Many problems of contemporary research interest in the fields of Applied Mathematics, Mechanics, Economical, Physical and Life Sciences are characterized by nonlinear behavior. Emergent phenomena such as multiplicity of steady states, self-sustained oscillations, phase-transitions and chaos are paradigms of such complex dynamics.

The aim of the course is to introduce and develop the modern theory of dynamical systems with a view to Bifurcation Theory in analyzing various problems in engineering and sciences.

The syllabus of the course:

1) Review of some basic non-linear phenomena. Examples from Mechanical Systems, NeuroScience, Material-Science, Bio-Systems and Financial Markets. Introduction to Nonlinear Dynamical Systems. Orbits, steady states, oscillations, phase diagrams. Attractors and Bifurcations. The Duffing oscillator without external forcing. The Van der Pol oscillator. Introduction to the theory of invariant manifolds, stable, unstable and central. 2) The Implicit Function Theorem. Local Bifurcations and Stability in one and two dimensions. Turning points, Double, Conjugate and Cusp points. The Factorization Theorem. Stability Analysis of Bifurcating solutions. 3) Normal forms of Turning points, Transcritical and Pitchork Bifurcations. Problems with Symmetry. Imperfection Theory and symmetry-breaking. Examples. Stability of symmetry-breaking solutions. 4) Bifurcations of Periodic solutions from steady states in two and greater than two dimensions. Hopf-Andronov

bifurcation. Analysis of Lorentz equations. 5) Poincare maps. The periodically forced Duffing oscillator. Stability of periodic solutions of autonomous systems. The Monodromy matrix. Bifurcations of fixed points of maps. 6) Bifurcations of limit cycles. Period-doubling bifurcation, Torus. The example of FitzHugh-Nagumo equations in Neuroscience. Phase-locking. 7) Global bifurcations. Homoclinic, Heteroclinic Bifurcation. Theorem of Andronov-Leontovich. Melnikov's method for homoclinic orbits. 8) Routes to Chaos. Strange attractors. The Lorenz equations. Lyapunov exponents and their computation. Power spectra computations.

9TH SEMESTER

9210 ENVIRONMENTAL POLICY AND ETHICS

Traditional views for the relations between man and nature: Man and nature in Greek philosophy and Jewish religion. Christianity and nature. The scientific revolution and the concept of nature. Modern philosophy and nature.

Elements of environmental philosophy: Ecology: what it is and what it is not. Profound and shallow ecology. Metaphysical and epistemological problems. Moral, political and aesthetic problems. Animal rights. Eco-feminism. Technology, economy and environment. Environmental politics and environmental law in Greece and in European Union.

7TH SEMESTER

9324 NUCLEAR PHYSICS

Introduction to the nucleus: radius, mass, charge, binding energy. Stability of the nucleus. Shell model, magical numbers. Angular momentum, spin, coupling, electric and magnetic moments. α, β, γ decay. Dosimetry. Fission, fusion, nucleosynthesis.

7TH SEMESTER

9326 MATERIAL SCIENCE

Introduction, Atomic structure and chemical bonding in solid phase. Defects, Atomic defects, Doping, Defects at interfaces, Diffusion in solid phase, Fick's law, Diffusion mechanisms and experimental techniques for structure and defects characterization. Solid solutions, phase diagrams, alloys, phase kinetics, Experimental techniques for phase separation and phase-diagram studies. Amorphous phase, glass transition, Structural models for amorphous materials, Percolation theory, Material processing, thermal treatment, annealing, high pressure treatment, Material failure and damage Corrosion, Aging. Low-dimensional materials: layered structures, quantum wells, wires and dots. Heterostructures. Foulerines, Nanotubes. Technological materials: metals, ceramics, glass, polymers, and composites. Growth, Properties, Applications.

9TH SEMESTER
APPLIED PHYSICS
CONCENTRATION

9334 ELECTRONICS AND LABORATORY – II

Measurement techniques. Instruments and measurements of electronic signals. Sources of noise, Circuit analysis and R, L, C analysis. Phasors. Sinusoidal and transitional response. Passive filters: high-pass, low-pass kai band-pass filters. Diode applications. Diode circuits. Rectifier configurations. Power electronics. Transistor applications. Bipolar and Field Effect transistors. Common emitter, base and collector amplifier. Operational amplifiers. Linear circuits based on operational amplifier. Non linear circuits based on operational amplifier. Differential amplifier. Application circuits. Digital circuits I: Boole Algebra, logical gates, combinational circuits and systems. Digital circuits II: Flip-Flops, sequential circuits and systems.

The course includes four laboratory exercises.

9344 EXPERIMENTAL PHYSICS

2ND SEMESTER
CORE PROGR.

2-hour introductory theoretical courses: Introduction, analysis of experimental results – Theoretical exercise 1. Presentation of experimental results – Theoretical exercise 2. The introduction is followed by 8 laboratory exercises (of 2-hour duration, mainly from electromagnetism) chosen among the following: Mapping of electric field. Study of the capacitance and measurement of the dielectric constant. Measurement of a solenoid's magnetic field. Measurement of the Cp/Cv ratio of gases. Measurement of the e/m ratio of the electron. Oscilloscope. Telemetry. Forced electrical vibrations, resonance. Measurement of the magnetic permeability of the vacuum μ_0. Calibration of a thermocouple.

An additional laboratory exercise chosen among the above mentioned ones is mandatory for those who miss one lab practice. In the end of the semester an additional theoretical exam is held, which constitutes a percentage of the final grade.

9346 INTRODUCTION TO PARTIAL DIFFERENTIAL EQUATIONS

4TH SEMESTER
CORE PROGR.

Fourier Series: Trigonometric series, Convergence theorems, special type Fourier expansions, generalized Fourier series, orthogonal coordinate systems, complete systems, Bessel inequality. ◆ *Boundary Value Problems*: Linear boundary value problems, eigenfunctions and eigenvalues,, Sturm-Liouville problems, non-homigeneous problems. ◆ *Introduction to Partial Differential Equations*: Fundamental notions, Classification of second order semi-linear differential equations. ◆ *Laplace equation*: The Dirichlet and Newmann boundary value problems. Compatibility condition. The separation of variables technique in Cartesian, polar, cylindrical and spherical coordinates. The non-homogeneous problem. Helmholtz equation. ◆ *Heat equation*: Initial-Boundary value problems for bounded domains, the no-homogeneous diffusion problem. ◆ *Wave equation*: Initial-Boundary value problems, the infinite length string, D'Alembert solution, the circular drum problem. ◆ *Integral transformations*: Fourier transform, Sine and Cosine Fourier transforms, Hankel transform, application of integral transforms to the solution of initial-boundary value problems.

Use of computational software for the study of problems arising in partial differential equations.

9348 COMPUTER PROGRAMMING WITH APPLICATIONS IN ENGINEERING SCIENCE

4TH SEMESTER
CORE PROGR.

Operating system: Introduction to UNIX like systems: System commands, utilities, redirection, piping, filters. Text processing commands. Shell scripting, text editor, plotting. Programming language: Introduction to Fortran, program structure. Compiler, optimization, profiling, debugging. Particle kinematics in 2 and 3 dimensions: Programming, data analysis, plotting. Error analysis and control, instabilities. Applications: Motion in the gravitational field of earth, magnetic field, harmonic oscillator, planet motion. Diffusion equation with and without source term in one and two dimensions: Solution in one and two dimensions, Courant number, finite differences, stenci. Solution in two dimensions in the presence of a source. Electrostatics: Field and equipotential lines of the electric field of a planar distribution of point charges. Solution of Laplace and Poisson equation on the plane. Calculation of trajectories, equilibrium and oscillating solutions in simple problems of neurostimulation: Lorentz equation. Parameter continuation for tracing solution diagrams. Phase diagrams. Simple Fitzhugh dynamic model for neurostimulation. Integration in time. Construction of solution diagrams. Calculation and plotting of the many particle system motion under the influence of coupled fields: Molecular dynamics on the plane, Verlet algorithm, boundary conditions. Plotting the motion. Equilibration, conserved quantities, position/velocity distribution. Accuracy of the solution. Molecular potentials: Hard sphere, Van der Waals and Lennard-Jones potentials. Logistic Equation: Programming for determining and visualizing the trajectory of the logistic equation. Attractors, fixed points, computation of solutions using iterative contraction maps (Newton-Raphson), bifurcating solutions. Period doubling, chaotic behaviour.

9353 SYSTEM RELIABILITY

8TH SEMESTER
APPLIED MATHEMATICS CONCENTRATION

Fixed time system reliability: structure of systems, reliability block diagrams, systems of independent components, reliability via inclusion/exclusion, system reliability bounds; Time dependent component/system reliability, Lifetime Distributions: failure rate and expected lifetime of a component/system, residual lifetime; Common lifetime distributions: exponential, Weibull, Gamma/Erlang, lognormal; Aging properties of components/systems: aging models, properties and reliability bounds, aging properties of monotone systems; Repair/maintenance policies: introduction to renewal theory, age-based component replacement, component repair vs replacement; Optimal repair/maintenance policies: replacement and inspection policies.

9545 MATHEMATICAL ECONOMICS

8TH SEMESTER

9547 COMPLEX DYNAMICS OF HAMILTONIAN SYSTEMS AND APPLICATIONS

5TH SEMESTER