**( It will be applied from 2019-2020 Fall)**

**İZMİR INSTITUTE OF TECHNOLOGY GRADUATE SCHOOL OF ENGINEERING AND SCIENCES DEPARTMENT OF PHYSICS CURRICULUM OF THE Ph.D. PROGRAM IN PHYSICS (FOR STUDENTS ENTERING WITH A BS DEGREE)**

| **Core Courses** | | | **ECTS** |
|---|---|---|---|
| PHYS 501 | Mathematical Methods of Physics I | (2-2)3 | 7 |
| PHYS 503 | Analytical Mechanics | (2-2)3 | 8 |
| PHYS 504 | Statistical Mechanics | (2-2)3 | 7 |
| PHYS 505 | Electromagnetic Theory I | (2-2)3 | 9 |
| PHYS 506 | Electromagnetic Theory II | (2-2)3 | 9 |
| PHYS 507 | Quantum Mechanics I | (2-2)3 | 9 |
| PHYS 508 | Quantum Mechanics II | (2-2)3 | 9 |
| PHYS 592 | Graduate Seminar II* | (0-2) NC | 7 |
| PHYS 599 | Scientific Research Methods and Ethics | (0-2) NC | 8 |
| PHYS 600 | Ph.D. Thesis | (0-1) NC | 26 |
| PHYS 8XX | Special Studies | (8-0) NC | 4 |

*All PhD students must register Graduate Seminar II course until the beginning of their 6th semester.

Total credit (min.) : 42 (for students with B.S. degree)
Number of courses with credit (min.): 14 (for students with B.S. degree)

| **Elective Courses** | | | **ECTS** | |
|---|---|---|---|---|
| PHYS 502 | Mathematical Methods of Physics II | (3-0)3 | 8 | |
| PHYS 511 | Condensed Matter Physics I | (3-0)3 | 7 | |
| PHYS 512 | Condensed Matter Physics II | (3-0)3 | 7 | |
| PHYS 513 | Physics of Semiconductors | (3-0)3 | 7 | |
| PHYS 514 | Physics of Semiconducting Devices | (3-0)3 | 7 | **Pre. PHYS 511** |
| PHYS 515 | Introduction to Superconductivity | (3-0)3 | 7 | |
| PHYS 516 | Superconducting Electronics I | (3-0)3 | 7 | |
| PHYS 517 | Superconducting Electronics II | (3-0)3 | 7 | |
| PHYS 518 | Thin Film Technology | (3-0)3 | 7 | |
| PHYS 519 | Surface Analysis Techniques | (3-0)3 | 7 | |

**( It will be applied from 2019-2020 Fall)**

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|---|---|---|---|---|
| PHYS 520 | Applications of Nanotechnology | (3-0)3 | 7 | |
| PHYS 521 | Low Temperature Physics | (3-0)3 | 7 | |
| PHYS 522 | Advanced Experimental Methods | (3-0)3 | 7 | |
| **PHYS 523** | **Fundamentals of Solar Cells** | **(2-2)3** | **7** | |
| PHYS 525 | Atomic and Molecular Spectra | (3-0)3 | 7 | |
| **PHYS 529** | **Optical Properties of Solids** | **(3-0)3** | **8** | |
| PHYS 530 | Quantum Optics | (3-0)3 | 7 | |
| PHYS 531 | Photonic Structures | (3-0)3 | 7 | |
| PHYS 532 | Applied Quantum Optics | (3-0)3 | 8 | |
| **PHYS 533** | **Quantum Information Theory** | **(2-2)3** | **8** | |
| PHYS 540 | Quantum Field Theory of Solids | (3-0)3 | 8 | |
| PHYS 541 | Quantum Theory of Many-Particle Systems I | (3-0)3 | 8 | **Pre. PHYS 504-508** |
| PHYS 542 | Quantum Theory of Many-Particle Systems II | (3-0)3 | 8 | **Pre. PHYS 541** |
| PHYS 551 | Particle Physics I | (3-0)3 | 8 | |
| PHYS 552 | Particle Physics II | (3-0)3 | 8 | **Pre. PHYS 551 or Consent of the Instructor** |
| PHYS 555 | Quantum Field Theory I | (3-0)3 | 8 | **Pre. PHYS 505-507 or Consent of the Instructor** |
| PHYS 556 | Quantum Field Theory II | (3-0)3 | 8 | **Pre. PHYS 555** |
| PHYS 557 | Quantum Field Theory III | (3-0)3 | 8 | **Pre. PHYS 556** |
| **PHYS 558** | **Quantum Field Theory in Curved Space** | **(3-0)3** | **8** | |
| PHYS 559 | Symmetries in Particle Physics | (3-0)3 | 8 | |
| PHYS 560 | Group Theory for High Energy Physics | (3-0)3 | 8 | |
| PHYS 561 | Fundamentals of the Standard Model of Particle Physics | (3-0)3 | 8 | |
| PHYS 562 | Supersymmetry I | (3-0)3 | 7 | **Pre. PHYS 555** |
| PHYS 563 | Supersymmetry II | (3-0)3 | 7 | **Pre. PHYS 562** |
| PHYS 570 | General Relativity | (3-0)3 | 8 | |
| **PHYS 571** | **Cosmology I** | **(3-0)3** | **8** | **PHYS 572** |
| **Cosmology II** | | **(3-0)3** | **8** | |
| PHYS 575 | Astrophysics I | (3-0)3 | 8 | |
| PHYS 576 | Astrophysics II | (3-0)3 | 7 | |
| PHYS 577 | Galaxies and Cosmolgy | (3-0)3 | 8 | |
| PHYS 578 | Structure and Evolution of Star | (3-0)3 | 8 | |
| PHYS 585 | Atmospheric Physics | (3-0)3 | 8 | |
| PHYS 586 | Atmospheric Radiation | (3-0)3 | 8 | |
| PHYS 587 | Climate Modeling | (3-0)3 | 8 | |

**( It will be applied from  2019-2020 Fall)**

| | | | |
|---|---|---|---|
| PHYS 588 | Cloud Physics | (3-0)3 | 8 |
| PHYS 590 | Special Topics in Physics | (3-0)3 | 7 |

**Doctoral Qualifying Examination:**

Every student registered to IYTE PhD Program in Physics has to take this exam which consists of the core courses in the graduate program. The general admission requirements stated under the Regulations Governing Graduate Education at IYTE are valid.

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## İZMİR INSTITUTE OF TECHNOLOGY GRADUATE SCHOOL OF ENGINEERING AND SCIENCES DEPARTMENT OF PHYSICS CURRICULUM OF THE Ph.D. PROGRAM IN PHYSICS

### COURSE DESCRIPTIONS

**PHYS 501 Mathematical Methods of Physics I (2-2)3 ECTS 7**

Mathematical techniques as applied to the equations of theoretical physics. Linear vector spaces. Calculus of variations. Sturm-Lioville problem.

**PHYS 502 Mathematical Methods of Physics II (3-0)3 ECTS 8**

Green's function. Integral transforms. Integral equations

**PHYS 503 Analytical Mechanics (2-2)3 ECTS 8**

Review of Newtonian dynamics and kinematics, Lagrangian dynamics, small oscillations, Hamiltonian dynamics, canonical transformations, mechanics of continuous systems.

**PHYS 504 Statistical Mechanics (2-2)3 ECTS 7**

Laws of thermodynamics. Microcanonical, canonical, and grand canonical distributions. Applications to lattice vibrations, ideal gas, photon gas. Quantum statistical mechanics; Fermi and Bose systems. Phase transitions and broken symmetries: universality, correlation functions, and scaling.

**PHYS 505 Electromagnetic Theory I (2-2)3 ECTS 9**

Electrostatics; boundary value problems; multipoles, electrostatics of macroscopic media and dielectrics; magnetostatics; time- varying fields, Maxwell equations; plane electromagnetic waves and wave propagation

**PHYS 506 Electromagnetic Theory II (2-2)3 ECTS 9**

Wave guides. Covariant formulation of Maxwell's equations. Special relativistic formulation of electromagnetic theory. Radiation theory.

**PHYS 507 Quantum Mechanics I (2-2)3 ECTS 9**

The fundamental principles of quantum mechanics, applications to simple systems, angular momentum, three-dimensional spherically symmetric potentials, scattering canonical formalism, spin.

**PHYS 508 Quantum Mechanics II (2-2)3 ECTS 9**

Rotations and symmetries in quantum mechanics, time-independent and time-dependent perturbation theory, identical particles, the quantum theory of radiation, second quantization, relativistic wave equations.

**PHYS 511 Condensed Matter Physics I (3-0)3 ECTS 7**

Principles and applications of quantum theory of electrons and phonons in solids. Structure, symmetry and bonding. Electron states and excitations in metals and alloys. Transport properties. Surfaces

**PHYS 512 Condensed Matter Physics II (3-0)3 ECTS 7**

Principles and applications of the quantum theory of electrons and phonons in solids. Phonon states in solids. Transport properties. Electron states and excitations in semiconductors and insulators. Defects and impurities. Amorphous materials. Magnetism. Superconductivity

**( It will be applied from 2019-2020 Fall)**

**PHYS 513 Physics of Semiconductors (3-0)3 ECTS 7**

Electronic structure; electrons in periodic structures. Semiconductor band structures. Pseudo-potential and method. Doping in semiconductors. Optical and transport properties of crystalline and amorphous semiconductors. Junction theory. Boltzmann transport equation. Interaction of phonons with semiconductors. Excitions. Semiconductors in magnetic fields. Hall effect. Quantum devices

**PHYS 514 Physics of Semiconducting Devices (3-0)3 ECTS 7**

Energy bands. Carrier transport phenomena. Bipolar devices: p-n junctions, bipolar transistors. Unipolar devices: MS Contacts, JFET and MESFET, MIS diode, MOSFET. Microwave devices. Photonic Devices: light-emiting diodes, semiconductor lasers, photo-detectors.

**Pre. PHYS 511 Condensed Matter Physics I**

**PHYS 515 Introduction to Superconducitivity (3-0)3 ECTS 7**

Critical temperature. Field and current. Meisener effect. Penetration depth. Coherence length. Thermal properties. Flux pinning. Tunneling. BCS theory. High-TC superconductors

**PHYS 516 Superconducting Electronics I (3-0)3 ECTS 7**

Foundations of Josephson effect. Macroscopic quantum phenomena: The Macroscopic quantum model.
Flux quantization. Josephson effect. Josephson Junction's (JJ): The zero voltage state. Basic properties of Lumped Josepson junctions, Short JJs, Long JJs. JJ's Voltage state: The basic properties of the lumped JJ's. Effect of thermal fluctuations. Voltage state of extended JJ's.

**PHYS 517 Superconducting Electronics II (3-0)3 ECTS 7**

Applications of the JJs: The DC SQUID, RF SQUID. Instruments based on SQUIDs. Application of SQUIDS. Digital electronics with SQUIDs: RSFQ circuits, RSFQ logics. Microwave resonators. Filters and detectors. Superconducting quantum bits. Two level systems. Quantum computation concepts with qubits.

**PHYS 518 Thin Film Technology (3-0)3 ECTS 7**

Review of crystal structures. Vacuum science. Thin film deposition. Evaporation. Plasma. Ion beam. Sputtering. Epitaxy. Chemical methods. Doping (*in situ*, *ex situ*). Diffusion. Structure. Defects. Interfaces. Thin film characterization methods: Optical, mechanical, electrical, magnetic. Integrated device technology.

**PHYS 519 Surface Analysis Techniques (3-0)3 ECTS 7**

Instrumental techniques for the characterization of surfaces of solid materials. The following analysis methods are discussed:X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), secondary ion mass spectroscopy (SIMS), Rutherford back scattering (RBS), scanning and transmission electron microscopy (SEM, TEM), energy and wavelength dispersive X-ray analysis; principles of these methods, quantification, instrumentation and sample preparation.

**PHYS 520 Applications of Nanotechnology (3-0)3 ECTS 7**

Basic physical, chemical, and biological principles in nano-areas.fNanoscale Fabrication. Nanomanipulation. Nanolithography. Top-down and bottom-up nanofabrication techniques. Self-assembled monolayers/dip-pen. Soft lithography. PDMS molding. Nanoparticles. Nanowires. Nanotubes, Nanocomposites. Nanocharacterization techniques. Electrical microscopy: TEM, SEM, SPM. Nanomedicine applications. Nanosensors.

**( It will be applied from 2019-2020 Fall)**

**PHYS 521 Low Temperature Physics (3-0)3 ECTS 7**

Solid matter at low temperatures. Properties of cryoliquids. Low temperature thermometry. Thermal contact and thermal isolation. Production of temperatures to 1 K. Dilution refrigerators. Adiabatic nuclear demagnetization. Superconducting magnets. Quantum fluids. Superconductivity. Bose-Einstein condensation.

**PHYS 522 Advanced Experimental Methods (3-0)3 ECTS 7**

Instrumental techniques for the characterization of surface and bulk of solid materials.The following analysis methods are discussed:X-ray photoelectron spectroscopy (XPS), scanning and transmission electron microscopy (SEM, TEM), energy and wavelength dispersiveX-ray analysis; photolitography, SPM scanning probe microscopy, principles of these methods, quantification, instrumentation and sample preparation.

**PHYS 523 Fundamentals of Solar Cells (2-2)3 ECTS 7**

General overview of semiconductors, Bandgap of materials and their classifications, p-n junctions, Photovoltaic effect, Interaction of light and material, Photoelectric effect, Working principle of solar cells, General concepts of solar cells like open circuit voltage, short circuit current, efficiency of a solar cell, Types of solar cells, Inorganic solar cells, Current projects on solar cells.

**PHYS 525 Atomic and Molecular Spectra (3-0)3 ECTS 7**

**R**eview of Bohr theory and Schrodinger equation. Fine structure and hyperfine structure. Zeeman effect. Intensities and multiplet analysis. Selected topics in molecular structure, such as treatment of rigid rotator, harmonic oscillator, infrared and Raman spectra, analysis of band structure

**PHYS 529 Optical Properties of Solids (3-0)3 ECTS 8**

Fundamental theory with emphasis on the relationship between electronic structure and optical properties of solids. Representative semiconductors, insulators and metals; impurities and defects in solids; optical properties of low dimensional structures; photoluminescence.

**PHYS 530 Quantum Optics (3-0)3 ECTS 7**

Review of QM. Harmonic oscillator quantization. Lattice vibrations and their quantization. Electromagnetic fields and their quantization. Number states, coherent states, squeezed states. Optical resonators. Interaction of radiation and atomic systems. Laser oscillation. Specific laser systems. Nonlinear optics. Stimulated Raman and Brillouin scattering

**PHYS 531 Photonic Structures (3-0)3 ECTS 7**

Review of Maxwell's equations, basic crystallography, Fourier series. 1D periodic systems. 2D and 3D photonic crystals. Calculation of the photonic band structure. Plane wave expansion, augmented plane wave method. KKR method. Point and line defects in photonic crystals. Photonic crystal optical fibers. Fermi's golden rule. Electromagnetic radiation in a photonic crystal, and inhibition of spontaneous emission. Various applications of photonic crystals.

**PHYS 532 Applied Quantum Optics (3-0)3 ECTS 8**

Review of quantum mechanics, introduction to quantum optics, photon statistics, atom-light interactions, cavity-quantum electrodynamics, non- linear processes for single-photon generation, quantum emitters, review of important recent quantum optical experiments.

**( It will be applied from 2019-2020 Fall)**

**PHYS 533 Quantum Information Theory (2-2)3 ECTS 8**

Review of Basic Postulates of quantum mechanics, Qubits and Bloch Sphere Representation, Density matrix formalism, Open quantum system and quantum measurement, quantum entanglement and its applications, quantum cryptography, entropy and information, entanglement witnesses and measures, quantum computation and algorithms, physical realization and experiments

**PHYS 540 Quantum Field Theory of Solids (3-0)3 ECTS 8**

Bose operators, field quantization, second quantization, interaction Picture of quantum mechanics, excitons, plasmons, magnons, electron-phonon interaction, polarons, Green's functions, BCS superconductivity, polaritons.

**PHYS 541 Quantum Theory of Many-Particle Systems I (3-0)3 ECTS 8**

Second quantization. Kubo linear response. Zero-temperature Green's functions, *S*-matrix expansion, Feynman diagrams, Feynman rules, various one- and two-particle Green's functions. Applications using the Anderson impurity model, Coulomb gas, Hubbard model and the electron-phonon interaction.
**Prerequisite: PHYS 504 Statistical Mechanics and PHYS 508 Quantum Mechanics II**

**PHYS 542 Quantum Theory of Many-Particle Systems II (3-0)3 ECTS 8**

Matsubara finite temperature Green's functions. Wick's theorem, Feynman diagrams and Feynman rules for finite temperatures. Phonon mediated superconductivity, Cooper's two-electron problem, BCS effective Hamiltonian, gap equation, Bogoliubov quasiparticle operators, *t*-matrix many-body instability, tunneling, spin and charge response in the superconducting state. Spin-fluctuation mediated superconductivity, *p*-wave pairing in superfluid $He^3$, *d*-wave pairing in high-temperature superconductors. **Prerequisite: PHYS 541 Quantum Theory of Many-Particle Systems I**

**PHYS 551 Particle Physics I (3-0)3 ECTS 8**

Elementary particles and their interactions, including important features of experimantal data. Classification of particles. Conservation laws. Strong, weak and electromagnetic interactions, V-A currents, intermediate vector bosons. Dinelastic scattering. CKM matrix. CP violation; neutrino oscillations.

**PHYS 552 Particle Physics II (3-0)3 ECTS 8**

Gauge theories. Spontaneous symmetry breaking. Brief review of quantum field theory and Feynman diagrams. The standart model of strong and electroweak interactions. Extended electroweak models. Unified theories and their theoretical, experimental and cosmological implications.
**Prerequisite: PHYS 551 Particle Physics I or consent of the instructor.**

**PHYS 555 Quantum Field Theory I (3-0)3 ECTS 8**

Brief overview of Poincare group, Dirac equation, Noether's theorem, and canonical quantization method. Feynman rules for scalars and QED, CPT and spin-statistics. One loop effects.
**Pre. PHYS 505 Electromagnetic Theory I and PHYS 507 Quantum Mechanics I or consent of the instructor.**

**( It will be applied from 2019-2020 Fall)**

**PHYS 556 Quantum Field Theory II (3-0)3 ECTS 8**

Path integral formulation of QFT. Renormalization and renormalization group. Parton model. Non-Abelian gauge theory. Feynman rules for gauge theories and Fadeev-Popov ghosts. Asymptotic freedom in QCD. **Pre. PHYS 555 Quantum Field Theory I**

**PHYS 557 Quantum Field Theory III (3-0)3 ECTS 8**

Operator product expansion, perturbation theory anomalies, spontanteous symmetry breaking, electroweak theory, perturbative QCD.

**Pre. PHYS 556 Quantum Field Theory II**

**PHYS 558 Quantum Field Theory in Curved Space (3-0)3 ECTS 8**

Brief overview of quantum field theory in Minkowski space, quantum fields in expanding universe, quantum fields in the de Sitter space, Unruh effect, Hawking effect, Casimir effect in curved space.

**PHYS 559 Symmetries in Particle Physics (3-0)3 ECTS 8**

Discrete and continous space–time symmetries. Internal symmetries. Global and local symmetries in particle physics. Manifest and hidden symmetries and their applications in high energy physics.

**PHYS 560 Group Theory for High Energy Physics (3-0)3 ECTS 8**

Groups, algebras , their representations, and applications in high energy physics. Basic aspects of permutation, orthogonal, unitary, symplectic groups. Lie algebras and groups, roots and weights. WignerEckart theorem and tensor methods. Clifford algebras and groups.

**PHYS 561 Fundamentals of the Standard Model of Particle Physics (3-0)3 ECTS 8**

Overview of observed particles and forces, spacetime and 4-vectors, relativistic kinematics. Brief introduction of Lagrangian formalism, electromagnetis, gauge invariance. Feynman rules and diagrams, cross-sections and decay rates. Overview of basic symmetries; SU(2) isospin, product representations, SU(3), C, P, and T. Hadrons and partons, quantum chromodynamics, electroweak theory.

**PHYS 562 Supersymmetry I (3-0)3 ECTS 7**

Representations of Lorentz group. Dirac and Weyl spinors.a Supersymmetry algebra. R-symmetry and central harges. Chiral superfields.Vector superfields.

**Pre. PHYS 555 Quantum Field Theory I.**

**PHYS 563 Supersymmetry II (3-0)3 ECTS 7**

Supersymmetry and renormalization. Minimal supersymmetric model.s Breakin of Supersymmetry. Local upersymmetry. Super Higgs mechanism.

**Pre. PHYS 562 Supersymmetry I**

**PHYS 570 General Relativity (3-0)3 ECTS 8**

Review of special theory of relativity.Tensor analysis and Riemannian geometry. Basic principles of general relativity. Einstein field equations. Gravitational waves, black holes, cosmology.

**( It will be applied from 2019-2020 Fall)**

**PHYS 571 Cosmology I (3-0)3 ECTS 8**

A brief overview of Robertson-Walker metric and the corresponding general relativity field equations, cosmological redshift and Hubble parameter, distances at small redshifts, luminosity and angular diameter distances, dynamics of expansion (a more detailed study of the field equations of RobertsonWalker metric), accelerated expansion and distances at large redshifts, different methods to determine the expansion of the universe (ages, galaxy masses, intergalactic absorption, number counts), scalar field models of dark matter and dark energy, cosmic microwave background and recombination era, primary fluctuations in cosmic microwave background, cosmological nucleosynthesis, fundamentals of inflation.

**PHYS 572 Cosmology II (3-0)3 ECTS 8**

General theory of small gravitational fluctuations, evolution of cosmological fluctuations, anisotropies in the microwave sky, growth of structure, gravitational lenses, inflation as the origin of cosmological fluctuations..

**PHYS 575 Astrophysics I (3-0)3 ECTS 8**

General properties of stars, stellar spectra, energy generation and transport in stars.

**PHYS 576 Astrophysics II (3-0)3 ECTS 7**

Stellar structure and evolution, Population I - Population II stars, stellar clusters, stellar rotation, stellar magnetic fields, stars with peculiar spectra, pulsating stars, explosive stars, active Sun, interstellar medium, Interstellar absorption

**PHYS 577 Galaxies and Cosmology (3-0)3 ECTS 8**

The Milky Way - our galaxy, classification of galaxies and properties of galaxies, active galaxies, introducing cosmology, cosmological theories, observational cosmology

**PHYS 578 Structure and Evolution of Stars (3-0)3 ECTS 8**

Observational properties: determination of stellar distances, fluxes and spectral energy distributions, masses, temperatures, etc. Stellar evolution: Approach to the main sequence: Hayashi evolution. Evolution of stars from the zero-age main sequence. Main-sequence stars and their evolution. End-points of stellar evolution: white dwarfs, neutron stars, black holes, supernovae. Clusters and their Hertzsprung-Russell diagram, stellar variability, stellar pulsations, binary stars. Applications and comparison of theory with observations.

**PHYS 585 Atmospheric Physics (3-0)3 ECTS 8**

Composition, species profiles, temperature, pressure and density. Atmospheric thermodynamics. Hydrostatic equation, applications of the first and the second laws, latent heat, adiabatic processes, static stability, equilibrium, water vapor amount. Aerosol and cloud microphysics: Aerosol nucleation and cloud droplet formation. Cloud types. Radiative transfer. Atmospheric dynamics: Rotating coordinate frames, fictitious forces, real forces, equation of continuity

**PHYS 586 Atmospheric Radiation (3-0)3 ECTS 8**

The atmospheric composition of the planets, and introduction to the physics of the atmospheric radiation. Black body radiation and radiation through gases from the viewpoint of Electromagnetic Theory and

Quantum Statistics. The derivation of radiation integrals and energy transport equations; applications to the Earth and other planet atmospheres. Band models, irradiance, atmospheric heating and cooling rates. Cloud radiation models.

**PHYS 587 Climate Modeling (3-0)3 ECTS 8**

Climate, climate change, and fundamentals of climate modeling. Parameterizations. Biosphere, lithosphere, hydrosphere, atmosphere interactions, and gridded parameterizations. Climate change predictions.

**PHYS 588 Cloud Physics (3-0)3 ECTS 8**

Thermodynamics of dry air, water vapor and thermodynamical effects, parcel buoyancy and atmospheric stability, mixing and convection, the observable properties of clouds, cloud droplet formation, condensation, rain in unsaturated clouds, ice crystal formation and growth, rain and snow, storms, weather modification, numerical weather prediction models.

**PHYS 590 Special Topics in Physics (3-0)3 ECTS 7**

Study of recent developments and advanced topics which are highly specific and do not fit in the usual regular courses. The department solicits student to chose the topics.

**PHYS 592 Graduate Seminar II (0-2)NC ECTS 7**

Oral presentations on topics dealing with current research and technical literature. Includes presentations of the latest research results by guest lecturers, staff members and senior graduate students.

**PHYS 599 Scientific Research Methods and Ethics (0-2)NC ECTS 8**

Scientific methods, testing scientific hypotheses, scientific writing and publishing. Basic principles, integrity, autorship, responsible publication, references and citations. Sloppy research, scientific fraud, plagiarism, fabrication, duplication, ghost autorship.

**PHYS 600 Ph.D. Thesis (0-1)NC ECTS 26**

Preparation of Doctoral thesis under supervision of the graduate student’s supervisor(s). Required of all candidates for the degree of Ph.D.

**PHYS 8XX Special Studies (8-0)NC ECTS 4**

M.S. students choose and study a topic under the guidance of a faculty member, usually his/her advisor