Courses in English 2017-2018
Physics

Autumn 2017

FYSS6301 Electronics, part A, 4 ECTS – Autumn 1st period.

Study Objectives
At the end of this course, students will be able to apply Kirchoff's current and voltage laws. Students will be able to describe the characteristics of basic linear circuit elements (resistor, capacitor and inductor) and analyze the properties of DC and AC signals in simple passive and active circuits as well as analyze the properties of simple circuits by using their transient characteristics. They will be also able to describe the different components of power consumption in AC circuits and apply operational amplifiers in simple circuits.

Course description
Kirchoff's laws; nodal and mesh analysis techniques; DC and AC characteristics (current, voltage and power) of linear passive components and simple circuits; basic AC analysis of RC/RL/RLC circuits in both time and frequency domains; basics of electric motors, sensors and actuators; basics of electronic amplifiers; basic principles of operational amplifier circuits.

Completion mode
The course can be accomplished by passing the exam, doing exercises (including the tasks in the TIM web environment) and the laboratory work. From these the exam and the lab work are compulsory. The exercises are optional for passing the course, but they will affect the grading.

Evaluation criteria
For passing the course minimum of 36 points are required out of the maximum 72 points available in the course. The total amount points consists of three different parts with the following weights: 17 % exercises, 17 % laboratory work and 66 % exam. Additionally, student needs to gain at least half of the points in both the exam (max. 48 points) and the laboratory work (max. 12 points) in order to be graded (Note! minimum of 36 points in total is still needed). The shortcomings in the exercises can be compensated with good performance in the exam, in which case the contribution of the exam in the total grading would be 83 %. In this case, the maximum points in the exam are 60 and 30 points are required to pass.

FYSS3300 Nuclear Physics, 8 ECTS – every autumn since 2017

Study Objectives
At the end of this course, students will be able to use the semi-empirical mass formula and experimental atomic masses to calculate binding energies and separation energies as well as relate the terms of the semi-empirical mass formula to properties of the nucleon-nucleon interaction and the binding of nucleons in nuclei. Students will be able to identify a variety of experimental observables which indicate the need for a nuclear shell model and use the shell model to calculate the spin and parity of the nuclear ground state as well as to understand simple single-particle excitations and structure. They will be able to use rotational and vibrational models of nuclei in

order to extract properties related to collective effects, for example deformation. They will be able to use the radioactive decay law and apply it to real-world scenarios of radioactivity in the environment as well as applications of nuclear power as well as use Q value systematics in beta decay in order to calculate log-ft values and identify the different transitions and how they can relate to the nuclear shell model. Students will be able to make relations between models of the alpha decay process and experimental alpha decay data, calculations of electromagnetic transition rates using a simple model, compare the results to experimental data and draw conclusions about nuclear structure based on the outcome as well as calculate reaction rates in experiments given target thicknesses, cross sections and primary beam intensities. They will also be able to use the liquid droplet model to describe the nuclear fission process and list the important ingredients of a nuclear reactor and calculate different parameters of operational reactors.

Course description
Liquid droplet model of the nucleus; the nuclear shell model and single-particle states; deformed nuclei, vibrational nuclei; radioactivity; alpha decay, beta decay and electromagnetic transitions; basic use of nuclear reactions; interaction of radiation with matter; nuclear fission and operation of a nuclear power plant

Completion mode
Assignments, examinations

Evaluation criteria
Active participation in the lectures is expected. Weekly exercises are given and are subsequently discussed in a problem solving class. The final grade is based on exams (80%) and exercises (20%), 60 points in total. Exam points are from either Mid-term 1+2 (24 points out of 60, each), or a Final Exam (48 points).

FYSS3460 Fission and its Applications, 5 ECTS – Given on autumn semester 2nd period, every two years starting autumn 2017

Study Objectives
At the end of this course, students will be able to describe the fission process path and the nuclear physics making fission possible. Students will be able to explain how the fission yield distribution results from the process of nuclear fission and explain the energy transfer process during the nuclear fission. Students will be able to find information on fission cross section, fission product yield, fission neutron yield, etc. from public data bases. They will be able to name the main facilities and instrumentation used in contemporary fission-based research and explain their operation principles. Students will also be able to perform a criticality calculation of a simple nuclear reactor.

Course description
Fission processes: spontaneous and induced fission, delayed fission; nuclear fission models, in particular Brosa model; fission yield distributions, fission neutrons, gamma ray emission; contemporary research on fission process; contemporary research utilizing fission and fission products; nuclear reactors and production of nuclear power

Completion mode
Assignments, writing assignments, examination

Prerequisites
Before enrolling this course students should have studied or currently studying FYSS3300 Nuclear Physics.

Evaluation criteria
The final grade is based on examination (70%), assignments (20%) and a writing assignment (10%).

FYSS4456 Experimental Methods in Particle Physics, 5 ECTS – autumn 2nd period, every year.

Study Objectives
At the end of the course, students will be able to qualitatively explain how common detectors in particle physics work. They will be able to simulate proton-proton collisions with PYTHIA event generator and explain the basics of phenomenology implemented in PYTHIA-code as well as use ROOT-packet in the data analysis. They will be able to ably apply invariant mass method when applicable and use the FastJet-packet in jet reconstruction. Also, they will be able to use basic methods to correct measured raw signal, particularly mixed events method and correcting finite detector efficiency.

Course description
ROOT, PYTHIA and FastJet program packets and data analysis using these packets; basics of detection of particles; phenomenology of proton-proton collisions; finite acceptance, detector efficiency; mixed event method; methods to subtract the background from raw signal; invariant mass method; (azimuthal) two-particle correlations; jet reconstruction

Completion mode
Programming assignments, project work.

Prerequisites
Particle physics (FYSS4300), which can be taken simultaneously. The course contains programming in C++ and thus, programming experience with some object oriented language is assumed.

Evaluation criteria
Course points are earned from weekly programming assignments (50 %) and programming project work (50 %). Passing of the course requires that project work is returned and accepted, and 50 % of the total points is reached. The project work is accepted when minimum of 50 % of its portion to course grading is achieved.

FYSS4540 Neutrino Physics, 5 ECTS - Given on autumn semester 2nd period, every two years starting autumn 2017

Study Objectives
At the end of this course, students will be able to use the basic notions and phenomena of neutrino physics. They will master the mathematical models of neutrino physics and are able to use them

creatively. They will also be able to read topical research literature of the field on a level needed for starting his/her own research work in neutrino physics.

Course description

Field theoretical description of neutrinos, as a part of the Standard Model; neutrino mass models and the effects of masses; neutrino oscillations.

Completion mode

Assignments, examination.

Prerequisites

Students enrolling for the course are expected to be able to demonstrate skills and knowledge listed in the learning objectives for the courses Quantum Mechanics (FYSA2031, FYSA2032) and Particle Physics (FYSS4300).

Evaluation criteria

The final grade is based on assignments (30 %) and examination (70 %).

FYSS5120 Efficient Numerical Programming, 4 ECTS - Given on autumn semester 1st period, every two years starting in autumn 2017

Study Objectives

At the end of the course, students will be able to combine coding with python and C++ and write C++ code that uses libraries for solving problems. Students will be able to understand the layout and inner workings of a C++ code, keep C++ code and the underlying mathematics in close unison as well as hide uninteresting or already well-tested programming details from daily view.

Course description

Efficient C++ programming for practical numerical applications; calling C++ from Python; using program libraries e.g. GSL and Boost libraries; numerically efficient data structures; benefits and caveats of operator overloading; debugging code, finding memory leaks

Completion mode

Programming assignments

Prerequisites

Programming experience with Python, C++ or some other programming language.

Evaluation criteria

Accepted solutions to programming assignments.

FYSS5455 Electron, Photon and Ion Beam Methods in Materials Science, 5 ECTS - Given on autumn semester 1st period, every two years starting autumn 2017

Study Objectives

The course is a thorough package of modern materials research techniques, focusing to those ones we have available here in Jyväskylä. It is useful for nanoscientists as well as for student specializing in materials or nuclear physics. It is also well suited for a chemist specializing in materials research. At the end of this course, students will be able to explain the fundamentals of different thin film deposition techniques and describe the fundamentals, possibilities and limitations of different thin film analysis techniques and detectors used in these techniques. Students will be able to select the most useful technique for each analysis problem, perform ion beam analysis measurements under supervision and do independent analysis of the measured data and perform measurements with at least one non-accelerator based analysis technique.

Course description
Interaction of energetic ions, electrons and photons with matter; thin film deposition techniques; ion, electron and photon beam based characterization techniques for thin films and surfaces; project work, which consists of growth of thin films using atomic layer deposition, characterization of thin films using at least two different techniques, reporting performed analysis and presenting results in a seminar.

Completion mode
Assignments, project work, examination.

Prerequisites
It is recommended that students enrolling to the course have completed a course in Measurements Techniques and Systems (FYSS6310) or a similar course.

Evaluation criteria
The final grade is based on final exam (60 %), home exercises (20 %) and project work (20 %).

FYSS5456 Helium Ion Microscopy, 1 ECTS - Given on autumn 2017, after which given when needed

Study Objectives
At the end of this course, students will be able to describe the working principle of helium ion microscopy (HIM) and conclude the advantages and disadvantages of HIM compared to other microscopy techniques. Students will be able to evaluate and justify the application of HIM to imaging of specific samples, such as biological samples and materials science and nanotechnology samples. They will have mastered the HIM principles and practice of tuning and using HIM for imaging to such extent that he/she can be trained to the use of the tool in a short time period.

Course description
The working principle of HIM; advantages of HIM compared to conventional SEM (resolution, ability to image non-conductive samples, material processing with neon beam); practical use of HIM; sample preparation of HIM.

Completion mode
Discussions and interactive events, demonstration, examination.

Evaluation criteria
Participation on course events and demonstration is a requirement for grading. To pass the course students need to have a pass from the examination.

FYSS6310 Measuring Techniques and Systems, 5 ECTS – Given on autumn semester 2nd period, every year

The course will be given either in Finnish or in English depending on the audience

Study Objectives

At the end of this course, students will be able to name SI units and describe their definitions as well as explain basic concepts of metrology traceability, calibration, uncertainty. Students are able to explain function of different parts of measurement system and compare different sensor/transducer types and select the most suitable for the application. They will be able to measure electrical quantities, identify sources of noise and eliminate them from a measurement system. They will be able to devise a simple measurement system in order to measure physical quantities and construct a simple computer aided measurement in LabView environment as well as explain operating principle of a lock-in amplifier.

Course description

SI units; metrology; measuring physical quantities; transducers; protection against noise sources; signal processing; computer aided measurement

Completion mode

Assignments, laboratory work, examination

Evaluation criteria

The final grade is based on the examination (50 %), laboratory work (30 %) and assignments (20 %). To pass the course, students need at least 50 % of the examination points. Full points from the assignments require that students have successfully completed 80 % of the assignments. All laboratory work must be completed successfully.

FYSS6351 Fluid Mechanics 1, part A, 5 ECTS – Scheduled Autumn semester 1st period, every year

The course will be given either in Finnish or in English depending on the audience

Study Objectives

At the end of this course, students will be able to use vector and tensor algebra in solving problems in fluid mechanics. Students will be able to classify a flow situation and choose the relevant equations in order to solve a related problem and distinguish a Newtonian and a non-Newtonian fluid when given the viscosity behavior of the fluid. They will be able to calculate the pressure distribution of a static fluid and the resulting forces on immersed planar surfaces. They will also be able to find equations for streamlines and pathlines in a simple flow field as well as utilize the Reynolds transport theorem and conservation laws in a macroscopic level in solving problems in fluid mechanics.

Course description

Basics of vector and tensor analysis; classification of flow conditions: time dependence, compressibility, friction, turbulence; classification of fluids based on viscosity properties; key consepts of fluid mechanics: pressure, velocity, shear stress, viscosity; Reynolds transport theorem; conservation of mass, momentum and energy

Completion mode
Assignments, examination, laboratory work

Evaluation criteria
To pass the course, students need to have at least the minimum score defined by the teacher for assessments: assignments and examination. The course grade is divided into component parts and each part is worth some percentage of the total grade (e.g. 20 % assignments, 80 % examination). In addition, laboratory work is a compulsory part of the course assessment.

FYSS6352 Fluid Mechanics 1, part B, 4 ECTS – Scheduled Autumn semester 2st period, every year

Study Objectives
At the end of this course, students will be able to calculate the material derivative of a given quantity when the flow field is known as well as solve an unknown field in simple and well defined flow conditions. Students will be able to assess what conditions must be satisfied in order for a solution to the flow equations to exist and derive the Navier-Stokes equation starting from microscopic conservation laws. They are also able to formulate the stream function and the velocity potential for a given flow field and knows when they exist and derive new solution for frictionless plane flows from the elementary solutions. They are also able to apply the theory of frictionless plane flows to simple problems.

Course description
Material derivative, convective derivative; microscopic conservation laws: mass, momentum, angular momentum, energy; material laws, viscosity; Euler equation, Stokes equation, Navier-Stokes equation; solving flow equations: boundary and initial conditions; stream function and velocity potential; fictionless plane flows, elementary solutions and their superposition; basics of airfoil theory

Completion mode
Assignments, examination, laboratory work

Completion mode
To pass the course, students need to have at least the minimum score defined by the teacher for assessments: assignments and examination. The course grade is divided into component parts and each part is worth some percentage of the total grade (e.g. 20 % assignments, 80 % examination). In addition, laboratory work is a compulsory part of the course assessment.

FYSS7435 Methods for Treating Stochastic Processes in Physics, 5 ECTS - Given on autumn semester, every year.

Study Objectives
At the end of this course, students will be able to describe stochastic systems with the theoretical methods developed for them, such as master equations, Fokker-Planck equation and Langevin equation, and can also solve these equations. Students will also be able to explain when these approaches are applicable in any given problem.

Course description
Different types of stochastic phenomena; Markov processes; master equation; quantum stochastic processes

Completion mode
Assignments, oral examinations

Evaluation criteria
To be eligible for grading, students need to submit a given number of assignments that are reviewed by the teacher. The final grade is based on oral examinations from which students need at least half of the total points.

FYSS7630 Many-particle Quantum Mechanics, 12 ECTS - Given on autumn semester, every year.

Study Objectives
At the end of this course, students will be able to derive the basic equations of many-body perturbation theory. They have acquired a broad conceptual understanding of the basic ideas behind many-body perturbation theory as well as introductory knowledge for independently reading the research literature on many-body theory.

Course description
The concepts of second quantization; the concepts of the many-particle Green function; the equations of motion and the self-energy; diagrammatic expansions for the Green functions, Feynman graphs; dressing and re-summation of diagrams

Completion mode
Discussions, assignments, project work

Prerequisites
Before enrolling to this course students are expected to have a basic knowledge of quantum mechanics.

Evaluation criteria
Active participation to the course is expected. The final grade is based on a final project (50 %), and problem set (50 %).To pass the course students need to have a final score of 50 %.

Spring 2018

FYSS5300 Condensed Matter Physics, 8 ECTS – every spring semester

Study Objectives
At the end of this course, students will be able to tell the main bonding mechanisms is solids, know the concept of a lattice and most important lattice types as well as know the difference between crystalline and amorphous materials. Students will be able to explain the concept of reciprocal lattice, and use it in solving diffraction problems, distinguish most defect types and define the wave equation for acoustic waves. Students will be able to solve the phonon dispersion relations of the simplest lattices, define the concept of phonon and tell, how it explains the thermal properties of insulators. They are able to describe how dielectrics influence the propagation of EM fields and

explain the concept of the free-electron model and tell, how one can use it to calculate electron density and heat capacity, explain Bloch's theorem and tell, how it determines the band structure, and describe the main features of the nearly-free electron and tight-binding models and explain, why some materials are metals and some other insulators. They are able to know the concepts of a hole and effective mass, explain how electrical conductivity arises from the microscopic picture and describe the basic principles behind magnetism and superconductivity.

Course description
Bonding in solids; crystal structure, amorphous materials, alloys; reciprocal lattice, experimental determination of crystal structure, X-ray and neutron diffraction; defects, introduction to elasticity, classical acoustic waves; lattice dynamics and phonons; thermal properties of phonons; dielectric properties, phonons and polaritons in ionic crystals; electronic structure of materials, free-electron gas, electronic heat capacity; electrons in a periodic potential, energy bands, nearly-free electrons, tight-binding approximation; metals, insulators, semiconductors; electron dynamics in bands, physics of conductivity, electronic thermal conductivity; introduction to magnetism and superconductivity.

Completion mode
Assignments, examination

Evaluation criteria
Students are expected to have at least 50 % of the course points to pass the course. To assess the students' learning, teacher can use a combination of different assessment methods and the course grade is divided into component parts, each part worth some percentage of the total grade (e.g. assignments 20 %, examination 70 % of the grade).

FYSS3440 Nuclear Astrophysics, 6 ECTS – Spring semester 2nd period, every two years starting spring 2018

Study Objectives
At the end of this course, students will be able to explain, where and how elements have been formed in the universe. Students will be able to explain which factors have an effect on thermonuclear reaction rates and classify and list thermonuclear reactions as well as calculate reaction rates for basic thermonuclear reactions in stars. They will also be able to give examples of nuclear astrophysics experiments and research.

Course description
Basic concepts in nuclear astrophysics; selected astrophysical aspects: stellar evolution, novae, core-collapse supernovae, type I x-ray bursts, neutron-star mergers, solar system abundances; nuclear reactions and in particular thermonuclear reactions; primordial nucleosynthesis; hydrostatic hydrogen burning in stars: pp chains and CNO cycles; explosive hydrogen burning in stars: rp process; helium burning in stars: production of carbon and oxygen in stars; carbon, neon, oxygen and silicon burning in stars; nucleosynthesis beyond the iron peak: s-, r- and p-processes; examples of nuclear astrophysics experiments

Completion mode
Assignments, examination

Prerequisites
Before enrolling to this course, students are expected to have a good understanding of the basic concepts in Nuclear Physics: nuclear mass and binding energy, mass excess; nuclear liquid drop model and shell model; radioactive decay law; beta and gamma decay and transition probabilities; cross section; fusion reactions and fission

Evaluation criteria
The final grade is based on examination and assignments. At least half of the maximum points is needed to pass the course.

FYSS3500 Mean Field Models in Nuclear Physics, 9 ECTS – every other spring starting 2018

Study Objectives
At the end of this course, students will be able to explain nuclear superfluidity, concept of quasiparticle and nuclear deformation. Students will be able to solve Hartree-Fock-Bogoliubov (HFB) equations numerically with a computer code and calculate deformation energy potential with constrained HFB. They will be able to calculate excited states in superfluid nuclei as well as evaluate calculated theoretical results against experimental data.

Course description
Bardeen-Cooper-Schrieffer (BCS) and Hartree-Fock-Bogoliubov (HFB) theories; nuclear deformation and deformed mean field; one and two-quasiparticle excitations; Quasiparticle Tamm-Dancoff Approximation (QTDA) and Quasiparticle Random Phase Approximation (QRPA) theories

Completion mode
Assignments, examination

Prerequisites
Before enrolling to this course, students are expected to have understanding of angular momentum algebra, nuclear mean field, second quantization, Hartree-Fock, electromagnetic and beta transitions and configuration mixing as well as basic Unix/Linux user skills.

Evaluation criteria

The final grade is based on the assignments (50 %) and the examination (50 %).

FYSS3550 Techniques for Nuclear and Accelerator-based Physics Experiments, 10 ECTS - Given on spring semester, every year starting spring 2018.

Study Objectives
At the end of this course, students will be able to operate various radiation detectors used in nuclear and accelerator-based physics experiments, construct measurement and coincidence circuits from modular electronics and acquire spectra using radiation detectors and recognise features of spectra from radiation detectors and relate them to the physical processes causing them. Students will be able to manipulate the trajectories of ions through a recoil separator and compare observations to ion-optical calculations, operate an ISOL-type mass separator and guide an ion beam through the system starting from previous beam line settings and experimentally determine the mass resolving power of a mass separator. They will be able to characterise the composition of thin films of materials using ion-beam techniques and predict the main features of the spectrum from a Rutherford Backscattering experiment based on reaction kinematics and interaction cross-sections. They will also be able to identify different radiation environments affecting electronic systems, diagnose the radiation sensitivity of simple electronic components, differentiate the radiation induced error types in electronics and their physical mechanisms and interpret radiation test data to estimate soft error rates

Course description
Interaction of radiation with matter; principles, construction and operation of radiation detectors; basics of signal processing in nuclear physics experiments; production, separation and manipulation of (radioactive) ions with energies in the eV to GeV range; methods to determine atomic masses; methods in Nuclear Spectroscopy; characterisation of materials with energetic ion beams; basic mechanisms of radiation effects in electronics; radiation environments governing the reliability of electronics

Completion mode
Laboratory work, written assignments, examination

Prerequisites

Students enrolling to this course are expected to have completed the course Nuclear Physics (FYSS3300).

Evaluation criteria
Active participation in the lectures is expected. The laboratory experiments will be carried out in small groups (2-4 persons) and are compulsory. The final grade is based on examination (30 %) and laboratory work and associated reports (70%).

FYSS4510 Quantum Field Theory, 11 ECTS – Given on spring semester, every year.

Study Objectives

At the end of this course, students will be able to quantize spin-0, spin-1/2 and spin-1 free field theories and derive Feynman rules for an interacting field theory from its Lagrange function. Students will be able to compute scattering cross sections for physical processes in the lowest order of perturbation expansion for example in the Yukawa theory and in QED. They will understand well the path integral methods and knows how to use them to quantize both Abelian and non-Abeliand gauge field theories in with differen gauge-choices. They will also understand the basics the renormalization program for scalar theory.

Course description

Canonical quantization, free scalar field; Greens function and propagator; spin and canonical quantization of free fermion field; symmetries and conservation laws, Noethers theorem, discrete P, C and T symmetries; interacting theories, S-matrix and cross sections, LSZ-reduction; perturbation theory: Wicks theorem and Feynman rules; computing tree level processes, Yukawa theory and QED; path integral methods and generating functions; path integral quantization of gauge theories; renormalization and regularization, canonical and BPHZ-method.

Completion mode

Interactive lectures, assignments, traditional examination, home examination

Evaluation criteria

The final grade is based on assignments (25-40 %) and examination (75-60 %). The weighting depends on the completion mode.

FYSS4515 Applied Quantum Field Theory, 11 ECTS – every spring

Study Objectives

At the end of this course, students will understand fully the content of the renormalization program and be able to apply renormalization methods to compute higher order corrections to scattering processes and to study the scale dependence of couplings. Students will be able to understand the particular features of renormalization of Yang-Mills gauge theories and be able to compute critical exponents using field theory methods. They will understand the meaning of the effective action and effective potential and knows how to compute quantum corrections to them. They will be able to fully undestand the structure and quantization of the standard model of electroweak interactions and know how to compute precision electroweak observables. They will undestand how chiral and ABJ-anomalies arise and what they mean for renormalizability.

Course description

Review of functional methods; systematics of renormalization, BPHZ-method; renormalization of QED and Ward identities, explicit 1-loop renormalization; infrared divergences and soft brehmsstrahlung; renormalization group: Wilsonian flow, Callan-Symantzik equation; beta functions and anomalous dimensions, one-loop running of couplings; renormalization of Yang-Mills theory, asymptotic freedom; Parton model and quark model for QCD; critical phenomena and epsilon-expansion, critical exponents; effective action and (RG-improved) effective potential; renormalization of spontaneously broken theories; standard Model of electroweak interactions; precision electroweak observables; quantum anomalies: chiral and conformal anomalies and ABJ-anomalies.

Completion mode
Interactive lectures, assignments, traditional examination, home examination.

Evaluation criteria
The final grade is based on assignments (25-40 %) and examination (75-60 %). The weighting depends on the completion mode.

FYSS5300 Condensed Matter Physics 8 ECTS – Given on spring semester, every year.

Study Objectives
At the end of this course, students will be able to tell the main bonding mechanisms is solids, know the concept of a lattice and most important lattice types as well as know the difference between crystalline and amorphous materials. Students will be able to explain the concept of reciprocal lattice, and use it in solving diffraction problems, distinguish most defect types and define the wave equation for acoustic waves. Students will be able to solve the phonon dispersion relations of the simplest lattices, define the concept of phonon and tell, how it explains the thermal properties of insulators. They are able to describe how dielectrics influence the propagation of EM fields and explain the concept of the free-electron model and tell, how one can use it to calculate electron density and heat capacity, explain Bloch's theorem and tell, how it determines the band structure, and describe the main features of the nearly-free electron and tight-binding models and explain, why some materials are metals and some other insulators. They are able to know the concepts of a hole and effective mass, explain how electrical conductivity arises from the microscopic picture and describe the basic principles behind magnetism and superconductivity.

Course description
Bonding in solids; crystal structure, amorphous materials, alloys; reciprocal lattice, experimental determination of crystal structure, X-ray and neutron diffraction; defects, introduction to elasticity, classical acoustic waves; lattice dynamics and phonons; thermal properties of phonons; dielectric properties, phonons and polaritons in ionic crystals; electronic structure of materials, free-electron gas, electronic heat capacity; electrons in a periodic potential, energy bands, nearly-free electrons, tight-binding approximation; metals, insulators, semiconductors; electron dynamics in bands, physics of conductivity, electronic thermal conductivity; introduction to magnetism and superconductivity.

Completion mode
Assignments, examination.

Evaluation criteria
Students are expected to have at least 50 % of the course points to pass the course. To assess the students' learning, teacher can use a combination of different assessment methods and the course grade is divided into component parts, each part worth some percentage of the total grade (e.g. assignments 20 %, examination 70 % of the grade).

FYSS5402 Quantum Optics, 7 ECTS – Spring semester 1st period, every year.

Study Objectives
At the end of the course, students will be able to investigate the quantum properties of the electromagnetic radiation and its interaction with matter with the necessary tools.

Course description
Quantization of the electromagnetic field; coherence properties of light (field-coherent, squeezed & generalised-coherent states); electromagnetic field representation (P, Q, Wigner); detection and open quantum systems (input-output formalism, master equation); nonlinear optical phenomena (parametric amplification & squeezing generation); light-matter interaction (resonant fluorescence, lasing, optomechanics); quantum optics and quantum information.

Completion mode
Discussions, assignments, laboratory work, examination.

Evaluation criteria
Active participation to the course events is expected. The final grade is based on a final exam (75 %) and exercise sessions/reviews (25 %). To pass the course students need to have a final score of 60 %.

Prerequisites
Prerequisites are that students are able to describe and analyze quantum many-body systems using second quantization formalism.

FYSS4556 Perturbative QCD, 7 ECTS - Spring semester, every two years

Study Objectives

At the end of this course, students will be able to deal with the SU(3) color algebra and compute color factors for various quark and gluon scatterings. Students will be able to compute perturbative QCD cross sections, correctly dealing with physical gluon polarization states, and define and apply parton distribution functions in collinearly factorized NLO perturbative QCD cross sections. They will be able to solve DGLAP scale evolution equations and compute cross sections for deep inelastic scattering (DIS) and Drell-Yan process in leading and next-to-leading order, and for jets in leading-order perturbation theory. They will also be able to compute decay widths of quarkonia using perturbative QCD in a non-relativistic limit.

Course description

SU(3) gauge transformations, gauge fixing, QCD Feynman rules; SU(N) color algebra: derivation of color identities and calculation of color factors for scattering cross sections; jet and inclusive hard hadron production in p+p collisions: kinematics and leading-order partonic cross sections, gluon polarization states and ghosts, parton distribution functions and fragmentation functions, collinear factorization; deep inelastic scattering: electroweak-current cases in leading-order perturbation theory, QCD-improved parton model, computation of the next-to-leading order QCD corrections and definition of the parton distribution functions, DGLAP scale evolution equation and its solutions; Drell-Yan dilepton process: kinematics, computation of the cross sections in leading and next-to-leading order perturbative QCD; decay of a quarkonium state using perturbative QCD in a non-relativistic limit

Completion mode

Assignments, examination.

Prerequisites

FYSS4300 Particle Physics

Evaluation criteria

Maximum points: 70% from the final exam plus 30% from the exercises; passing the course: at least 50% of the maximum total points obtained; maximum score from the exercises: at least 80% of all the available exercise points obtained.

NANS1004 Computational Nanosciences, 2 ECTS – Given on spring semester 2nd period, every year.

Study Objectives
At the end of this course, students are able to relate computational research to experimental and purely theoretical research. Students can differentiate and classify different methods in computational nanoscience with respect to their central approximations, quantum-mechanical characters, and computational efficiencies. They are able to justifiably choose the most appropriate computational methods once given the material system and the properties under investigation as well as independently deepen their methodological knowledge whenever necessary.

Course description
Viewpoints to computational research (material systems, methods, analysis, processes, computational infrastructure); overview of various computational methods (many-body methods, density-functional theory, tight-binding model, classical force fields, discretized continuum); suitability of different methods to investigate nanomaterial properties; computational research at NanoScience Center.

Completion mode
Discussions and interactive events, research project, participants teach.

Evaluation criteria
Compulsory lecture attendance (one absence allowed, second absence requires extra work). Assessment is based on project (written and oral presentation) and activity on lectures.

FYSS5540 Density Functional Theory, 8 ECTS

Study Objectives

After the course, students will be able to derive the key equations of density functional theory. Students have acquired a broad conceptual understanding of the basic ideas behind density functional theory as well as introductory knowledge for independently reading the research literature on density functional theory.

Course description

The one-to-one correspondence between external potentials and densities, the Hohenberg-Kohn theorem; the universality of the energy functional; the construction of the Kohn-Sham equations as an auxiliary system; the local density approximation and the gradient expansion; the Runge-Gross theorem and time-dependent density functional theory.

Completion mode

Discussions in the class, assignments, project work

Prerequisites

Basic knowledge of quantum mechanics is sufficient to follow the course.

Evaluation criteria

Active participation to the course is expected. The final grade is based on a final project (50 %) and problem set (50 %).To pass the course students need to have a final score of 50 %.

FYSS6325 Cryogenics, 5 ECTS – Spring semester 1st period (tentatively), every three years; scheduled for academic year 2017-2018

Study Objectives
At the end of this course, students will be able to name the main characteristics of cryoliquids, tell about the principles of the properties of solid matter at low temperatures as well as about the behavior of thermal conductivity at low temperatures. Students will be able to describe the operational principles of He3 and He4 cryostats and the operational principle of He3-He4 dilution refrigerators. They are able to explain the idea behind Pomeranchuck cooling and the mechanisms of

electronic and nuclear adiabatic demagnetization. They are able to define temperature scales and describe a few low-temperature thermometry techniques, examples of cryogenic devices, write a short description of one topic in cryogenics and give a seminar talk on one topic in cryogenics.

Course description
Properties of cryoliquids; solid matter at low temperatures; thermal conductance and isolation; Helium-4 and closed cycle cryostats; Helium-3 cryostats; He3-He4 dilution refrigeration; Pomeranchuck cooling; adiabatic demagnetization; adiabatic nuclear demagnetization; temperature scales and fixed points; low temperature thermometry; cryogenic devices

Completion mode
Assignments, participants teach (presentation), project work, examination

Evaluation criteria
To pass the course, students need to have at least the minimum score defined by the teacher for assessments (such as assignments, project work, participation, examination, total points). The course grade is divided into component parts (i.e. individual assessments) and each part is worth some percentage of the total grade (e.g. 30 % assignments, 10 % participation, 10 % project work, 50 % examination).

FYSS6335 Micro- and Nanofabrication, 7 ECTS – Given on spring semester 2nd period, every two years starting spring 2018.

Study Objectives
At the end of this course, students will be able to create a micro- or nanofabrication process from scratch and evaluate theoretically the outcome of different fabrication processes.

Course description
Development of the silicon planar process and lithography; thin films: Materials, general properties and characterization; deposition methods (Physical & chemical vapor deposition); etching methods (Dry, wet, plasma); doping methods (Diffusion & Ion implantation); nanoimprint lithography and self-assembly -based methods; state-of-the-art in microfabrication; the nanotechnology frontier

Completion mode
Examination, assignments, laboratory work

Prerequisites
Before enrolling for this course, students are expected to have studied the Experimental Methods in Physics (FYSA1110).

Evaluation criteria
Active participation to the course events is expected. The final grade is based on examination (70 %), assignments (15 %) and laboratory work (15 %). To pass the course students need to have a final score of 50 %.

FYSS6302 Electronics, part B, 4 ECTS

Study Objectives

At the end of this course, students will be able to describe different parts in a control system and differentiate the benefits and shortcomings in both negative and positive feedback. Students will be able to explain the basic principles of semiconductors and how doping affects them as well as apply semiconductor components (diodes and transistors) in basic circuits as well as construct basic amplifier circuits by using bipolar and MOS transistors. They will be able to classify and describe the different noise sources relevant to electronics components and systems and identify different data acquisition and conversion methods.

Course description

Open loop and closed loop control systems; positive and negative feedback in control systems; fundamentals of semiconductor physics; introduction to semiconductors devices: diodes and transistors (BJT and MOS); amplifier circuits and their classification; noise sources and their classification; introduction to data acquisition and conversion

Completion mode

The course can be accomplished by passing the exam, doing exercises (including the tasks in the TIM web environment) and the laboratory work. From these the exam and the lab work are compulsory. The exercises are optional for passing the course, but they will affect the grading.

Evaluation criteria

For passing the course minimum of 30 points are required out of the maximum 60 points available in the course. The total amount points consist of three different parts with the following weights: 17 % exercises and 83 % exam. Additionally, student needs to gain at least 24 points in the exam (max 48 points) and have the laboratory work accepted in order to be graded (Note! minimum of 30 points in total is still needed). The shortcomings in the exercises can be compensated with good performance in the exam, in which case the contribution of the exam in the total grading would be 100%. In this case, the maximum points in the exam are 60 and 30 points are required to pass. For grading, the general tables of the physics department are used.

FYSS6430 Röntgen Tomography and Image Analysis, 4 ECTS – Spring semester 1st period, every year

The course will be given either in Finnish or in English depending on the audience

Study Objectives

At the end of this course, students will be able to explain how X-ray tomographic devices function as well as use such devices. Students will be able to perform tomographic reconstruction and analyze three-dimensional images with suitable tools and algorithms. They will also be able to plan image-based measurements and evaluate uncertainty in the measurements.

Course description
Structure and operation of X-ray tomographic devices; image reconstruction and artifact reduction; basics of digital image processing; noise removal; segmentation; image-based measurements; visualization

Completion mode
Discussions and interactive events, project work, learning diary, assignments

Prerequisites
The student knows how to use statistical analysis to present data and a computer software meant for numerical calculation (for example MATLAB).

Evaluation criteria
The student is required to write a laboratory report and to complete at least 50% of the exercises.

FYSS6451 Fluid Mechanics 2, part A, 5 ECTS – Given on spring semester 1st period, every two years starting spring 2018

The course will be given either in Finnish or in English depending on the audience

Study Objectives
At the end of this course, students will be able to understand basics of dimensional analysis and can use it in planning experiments and solving flow-related problems. Students will be able to explain basics of frictional flow, instability and turbulence as physical phenomena as well as use the theory and phenomenology of turbulent flow to calculate loss in internal flows in terms of Moody's diagram and minor loss correlations. They will also be able to explain operation and basic theory of centrifugal pump, and use it to design e.g. pumping system.

Course description
Principle of dimensional homogeneity and dimensional analysis; phenomenology of frictional flow; energy equation of flow and the concept of frictional loss

Completion mode
Discussions and interactive events, assignments, laboratory work, examination

Prerequisites
Students enrolling for this course are expected to have successfully completed FYSS6351 Fluid Mechanics 1, part A.

Evaluation criteria
The final grade is based on examination (2/3), assignments (1/6) and laboratory work (1/6).

FYSS6452 Fluid Mechanics 2, part B, 4 ECTS – Given on spring semester 2nd period, every two years starting spring 2018

The course will be given either in Finnish or in English depending on the audience

Study Objectives

At the end of this course, students understand basic phenomenology of frictional boundary layer flow, including laminar and turbulent boundary layer, skin friction and separation of flow. Students will be able to use basics theories of frictional boundary layer flow to estimate e.g. drag on submerged bodies. They understands basic phenomena related to compressible flows, and differences to incompressible flows. They can also use the theory of adiabatic, isentropic and compressible flow to analyse flows in short ducts and nozzles. Also they understand most important features of supersonic flow.

Course description

Karman theory of boundary layer flow and boundary layer equations; frictional boundary layer along straight surface; frictional boundary layer along curved surface, criteria for separation of flow; basic equations and thermodynamics of compressible flow; supersonic flow and shock phenomena

Completion mode

Assignments, laboratory work, examination

Evaluation criteria

The final grade is based on examination (2/3), assignments (1/6) and laboratory work (1/6).

FYSS7320 General Relativity, 5 ECTS – Given on spring semester 1st period, every two years starting spring 2018.

Study Objectives

At the end of the course, students will be able to explain the basic concepts of special and general relativity and their differences. Students will be able to compute the transformation of tensor components under coordinate transformations and form covariant derivatives, compute distances between points of the spacetime using the metric as well as compute the connection coefficients and the curvature tensor from the metric. Students will be able to form the geodesics equations, understand their meaning and solve them in simple setups. Students will also be able to form Einstein equations by varying the action and understand their meaning as well as solve Einstein equations for a spherically symmetric, static, empty space outside a star (Scwartzschild) and compute orbits of test bodies and light and gravitational redshifts in the Schwartzschild space.

Course description

The course provides an introduction to General Relativity which is a classical theory of gravity. General Relativity describes gravity as curvature of the spacetime and it includes Newton's gravity as the weak field limit. Topics included contain a brief review of special relativity, introduction to differential geometry and curved spacetimes, Einsteins equations and curvature, Schwartzschild solution for stars and black holes and gravitational waves if time allows. In particular, the course aims to provide the theoretical background and tools useful for lecture courses on cosmology.

Completion mode
Assignments, examination

Prerequisites
Students are expected to have knowledge of Mechanics (FYSP1010) and Modern Physics (FYSA2001-2002).

Evaluation criteria
The final grade is based on the examination (75 %) and assignments (25 %)

Spring or autumn term

FYSS4300 Particle Physics, 8 ECTS

Study Objectives
At the end of this course, students will be able to use the terminology and concepts of particle physics, the Standard Model in particular. Students will be able to apply relativistic kinematics in various collision systems and apply the symmetry principle and conservation laws in finding the quantum numbers (spin, parity, C-parity, isospin) of particles in scattering and decay processes. They will be able to couple together different types of angular momenta or isospin operators and apply the resulting quantum number systematics and find the equations of motion of a theory, based on Euler-Lagrange equations as well as solve simple group-theory problems, do calculations in e.g. the SU(2) and SU(3) groups. They will also be able to find the solutions of the Klein-Gordon equation and Dirac equation of relativistic quantum mechanics derive the Lagrange densities of QED, QCD and electroweak unification theory on the basis of local gauge symmetry and apply the idea of spontaneous symmetry breaking and Higgs mechanism in different theories. In addition, they will be able to compute scattering cross sections and decay widths with Feynman rules in leading-order perturbation theory of QED, QCD, and electroweak unification theory and explain the purpose and arrangement of particle detectors e.g. at the LHC.

Course description
I. Particle phenomenology and calculation tools: Particle physics terminology and introduction to the Standard Model particles, interactions and Feynman graphs; relativistic kinematics in particle collisions; definition of a cross section and decay width; quantum numbers and conservation laws for leptons, quarks and gluons; space-time symmetries: Translational and rotational invariances and conservation of momentum and angular momentum, spatial inversion and parity, charge conjugation and C-parity; isospin symmetry, hadron quantum numbers and excited states; quark model of hadrons: quarkonium states, hadron spectrum and color confinement
II. Standard Model of particle physics: Basics of classical field theory: Euler-Lagrange equations, Noether's theorem, gauge symmetry in electrodynamics; basics of group theory; equations of

motion in relativistic quantum mechanics: Klein-Gordon equation and Dirac equation and their solutions; quantum electrodynamics (QED): local U(1) symmetry and QED Lagrange density, QED phenomenology and computation of scattering cross sections with QED Feynman rules in leading-order perturbation theory; quantum chromodynamics (QCD): local SU(3) symmetry and QCD Lagrange density, QCD phenomenology and computation of scattering cross sections with QCD Feynman rules in leading-order perturbation theory, asymptotic freedom; electroweak unification theory: handedness of neutrinos and antineutrinos, local SU(2)xU(1) symmetry and electroweak Lagrange density, spontaneous symmetry breaking and Higgs mechanism, derivation of the Standard Model Lagrange density with massive particles, Feynman rules, electroweak phenomenology, CKM matrix and quark mixing, Higgs physics; introduction to experimental particle physics.

Completion mode
Assignments, examinations.

Evaluation criteria
Maximum points: 80% from the final exam plus 20% from the exercises; passing the course: at least 50% of the maximum total points obtained; maximum score from the exercises: at least 80% of all the available exercise points obtained.

SUMMER SEMESTER

FYSS6455 Fluid Mechanics 3, 5 ECTS

Study Objectives

At the end of this course, students will be able to understand the basic principles and practices related to measurements, in general, as well as use the most important measuring techniques used in energy technology, in particular, for measuring temperature, pressure, gas content, flow rate, flow velocity and humidity of air. Students will also understand the basics of chemical analyses related to energy technology.

Course description

Basics of measurements; concepts of temperature and pressure, and principles of measuring temperature and pressure; methods for measuring total flow rate and flow velocity; factors related to gas content of liquids, and methods for measuring gas content; chemical content of liquids, and methods of chemical analysis

Completion mode

Assignments, laboratory work, examination

Evaluation criteria

The final grade is based on examination (2/3), assignments (1/6) and laboratory work (1/6).