## Core foundation courses:

## A-1

| **course title**: Group theory | **credits**: 2 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 1. | |
| prerequisites (if any): | |
| **course description**:<br>Group and homomorphism. Subgroups, cosets, normal subgroups and factor groups. Products of groups. Conjugacy classes, centralizers and derived subgroups. Elements of mathematical crystallography.<br>Lie groups: topological properties, Lie algebras and Haar measure. Representations and covering groups. The rotation group.<br>Group actions: orbits and stabilizers, classification of transitive actions, operations on actions.<br>Group representations: irreducibility, Schur's lemma, direct sums and tensor products, branching rules, characters and orthogonality relations, projective representations, symmetrized products, Frobenius-Schur indicators, induced representations and the reciprocity theorem, polynomial invariants.<br>Group presentations: free groups, Nielsen-Schreier theorem, generators and relations, Tietze transformations. | |
| **required readings**:<br><br>**recommended readings**:<br>Alperin-Bell: Groups and representations, Springer.<br>Robinson: Group theory, Springer.<br>Kirillov: Elements of the theory of representations, Springer. | |
| **course leader** (*name, title, acad. degree*): Bántay Péter, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**A-2**

| **course title**: Computer simulations in physics | **credits**: 2 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 1. | |
| prerequisites (if any): | |
| **course description**:<br>The goal of the course is to present an overview of computational physics through examples in various fields.<br>Topics: Numerical and analytical modeling. Model, algorithm, code. Machine precision. Serial and parallel architectures. Classical mechanics simulation. Complex dynamics, chaos, growth processes. Simulating thermodynamic systems. The role of randomness in simulations. Numerical optimization. Molecular dynamics, Verlet-algorithm. N-body simulations. Diffusion, flows, waves. Finite element method. | |
| **required readings**: Rubin H Landau, Manuel J Paez, & Cristian Bordeianu: A Survey of Computational Physics -introductory computational science , Princeton University Press, 2008<br>**recommended readings**: Computational Physics by J.M. Thijssen , (Cambridge University Press, 1999) | |
| **course leader** (*name, title, acad. degree*): István Csabai, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**A-3**

| **course title**: Methods of applied physics laboratory | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lab.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): pcm. | |
| semester: 1 | |
| prerequisites (if any): | |

**course description**:
The aim of the course to provide knowledge and practice on basic, modern measurement methods used in scientific research and engineering practice. During the semester each student performs seven 4-hour lab exercises and prepares the respective protocol.
The laboratory measurements:
- Single-crystal X-ray diffraction
- X-ray line profile analysis
- Transmission electron microscopy (TEM)
- Scanning electron microscopy (SEM)
- Atomic force microscopy (AFM)
- Liquid scintillation spectrometry
- Gamma spectroscopy
- Infrared spectroscopy
- Electron spin resonance

**required readings**:

**recommended readings**:
D. E. Newbury, D. C. Joy, P. Echlin, C. E. Fiori, J. I. Goldstein, Advanced Scanning Electron Microscopy and X-Ray Microanalysis, Springer US (1986)

**course leader** (*name, title, acad. degree*): Zoltán Dankházi, assoc. prof, CSc

**teacher(s)**, if any (*name, title, acad. degree*):
András Czirók, assist. prof., PhD
Jenő Gubicza, professor, DSc
Ákos Horváth, assoc. prof., CSc
Zsolt Kovács, assist. prof., PhD
Jenő Kürti, professor, DSc
János Lábár, assoc. prof., DSc
Péter Raffai, assist. lecturer, PhD
Bálint Szabó, assist. prof., PhD

## Specialized core courses:

### T-1

| **course title**: Atomic and molecular physics | **credits**: 4 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect., pc.<br>number of hours per week: 2+1<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 1 | |
| prerequisites (if any): | |
| **course description**:<br>Basics of quantum mechanical many-body theory<br>Perturbation theory, variational methods<br>Atoms with several electrons<br>Hartree-Fock approximation<br>Theoretical basics of molecules<br>Diatomic and polyatomic molecules<br>Interaction of atoms and molecules with magnetic fields<br>Interactions between atoms and molecules | |
| **required readings**:<br><br>**recommended readings**:<br>L D Landau,E. M. Lifshitz, Quantum Mechanics, 3rd Edition (Non-Relativistic Theory), Elsevier (2013)<br>Kapuy Ede, Török Ferenc, Az atomok és molekulák kvantumelmélete, Akadémiai Kiadó (1975)<br>Haken, H., Wolf, H.C., The Physics of Atoms and Quanta – Introduction to Experiments and Theory, Springer (2005)<br>Haken, H., Wolf, H.C., Molecular Physics and Elements of Quantum Chemistry – Introduction to Experiments and Theory, Springer (2004) | |
| **course leader** (*name, title, acad. degree*): András Csordás, assoc. prof.  , DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**T-2**

| | |
|---|---|
| **course title**: Nuclear physics | **credits**: 4 |
| course type (lect./sem./pc./lab./cons.): lect., pc.<br>number of hours per week: 2+1<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 1 | |
| prerequisites (if any): | |
| **course description**:<br>Basic properties of nuclei, mass, charge- and matter distribution, binding energy. Properties of excited states, energy, spin, parity, isospin, nuclear moments, level density. Features of the strong interaction, nucleon-nucleon scatterings. Weak and electromagnetic interactions of nuclei. Nuclear models, shell model, collective models, rotational and vibrational states. Nuclear reactions, direct and compound reaction models, resonances. | |
| **required readings**:<br>S. M. Wong: Introductory nuclear physics<br><br>**recommended readings**:<br>T. Fényes: Structure of atomic nuclei<br>W.S.C. Williams: Nuclear and particle physics | |
| **course leader** (*name, title, acad. degree*): Attila Csótó, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**T-3**

| **course title**: Particle physics | **credits**: 4 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect., pc.<br>number of hours per week: 2+1<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 1 | |
| prerequisites (if any): | |
| **course description**:Characterization of interactions, their field theoretic description, symmetries and conservation laws, discrete symmetries and the parity or the CP violation, low mass particles, strangeness, the barion and lepton numbers, the basis of the group theoretic description, non relativistic quark model, the Gell-Mann-Okubo mass formula, quantization of the electromagnetic field, light emission and absorption, quantization of fermionic fields, electron electron scattering, the Compton effect, electron positron annihilation | |
| **required readings**:<br>W. Greiner, J. Reinhardt: Quantum Electrodynamics (Springer, 1994)<br>D.H. Perkins: Introduction to High Energy Physics (Addison-Wesley, 1987)<br>T.P. Cheng, L.F. Li: Gauge theory of elementary particle physics (Oxford Univ. Press, 1988)<br><br>**recommended readings**: | |
| **course leader** (*name, title, acad. degree*): László Palla, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**T-4**

| | |
|---|---|
| **course title**: Statistical physics | **credits**: 4 |
| course type (lect./sem./pc./lab./cons.): lect., pc.<br>number of hours per week: 2+1<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 1 | |
| prerequisites (if any): | |
| **course description**: Review of the equilibrium statistical physics: ensembles. Ideal quantum gases. Interacting systems: expansions. Mean field theory. Stability of thermodynamic states, phase transitions. Condensed matter at low temperature: elementary excitations. Non-equilibrium ensembles, irreversibility, relaxation, linear response, Master equations. | |
| **required readings**: L. D. Landau and E. M. Lifshitz, Statistical Physics, Addison-Wesley (1969),<br>R. Kubo, Statistical Mechanics, North-Holland (1965), Franz Schwabl: Statistical Mechanics, Springer (2002), M. Plischke and B. Bergersen: Equilibrium Statistical Physics, World Scientific (2006), 3rd ed.<br><br>**recommended readings**:<br>Linda E. Reichl: A Modern Course in Statistical Physics, Wiley-VCH; 3rd Revised and Updated Edition edition, Pathria, R. K. (1972). Statistical Mechanics. Oxford: Pergamon. | |
| **course leader** (*name, title, acad. degree*): József Cserti, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**T-5**

| **course title**: Solid state physics | **credits**: 5 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect., pc.<br>number of hours per week: 3+1<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 1 | |
| prerequisites (if any): | |
| **course description**:<br>Symmetries and the role of broken symmetry in solid state physics. Quantum theory of lattice vibrations. Experimental and theoretical methods for band structure calculations. Semiclassical model of electron dynamics. Electrons in strong magnetic field. Transport and optical properties. Quantum theory of magnetism. Ginzburg–Landau theory and BSC theory of superconductivity. | |
| **required readings**: Jenő Sólyom: Fundamentals of the Physics of Solids: Volume 1: Structure and Dynamics, Springer; 2007 edition, Jenő Sólyom: Fundamentals of the Physics of Solids: Volume II: Electronic Properties, Springer; 2009 edition<br><br>**recommended readings**:<br>N. W. Ashcroft, N. D. Mermin: Solid State Physics (Holt, Rinehart and Winston, New York, 1976) | |
| **course leader** (*name, title, acad. degree*): József Cserti, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## Specialized differentiated courses:

## AF-1

| | |
|---|---|
| **course title**: Extragalactic astrophysics | **credits**: 3 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>75 percent of the lecture covers topics related to galactic dynamics, including: collisionless Boltzmann-equation, properties of elliptical galaxies, vertical and horizontal structure of disk galaxies. The remaining few lectures cover various other subjects, like: large-scale structure of the Universe, galaxy clusters and quasars. | |
| **required readings**:<br>James Binney, Scott Tremaine: Galactic Dynamics.<br><br>**recommended readings**:<br>Peter Schneider: Extragalactic Astronomy and Cosmology: An Introduction | |
| **course leader** (*name, title, acad. degree*): Zsolt Frei, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): Bence Kocsis, Assistant professor, PhD, Peter Raffai, Assistant professor | |

**AF-2**

| **course title**: General relativity | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>It lays the fundations to the next term course "Cosmology".<br>Syllabus: Curved coordinates, metric tensor. The principle of equivalence. Covariant derivatives. Riemannian, Ricci tensor. Energy-momentum tensor. Einstein's equations. Schwarzschild metric. Weak gravitational fields. Gravitational waves. Experimental evidence: precession of apsides, light deflection, Gravity Probe B experiment, Hulse-Taylor pulsar. Friedmann–Robertson–Walker metric. Expansion of the universe, red shift. Cosmological constant. Cosmological inflation. | |
| **required readings**:<br><br>**recommended readings**:<br>L.D. Landau, E.M. Lifshitz (1975). "The Classical Theory of Fields". Vol. 2 (4th ed.). Butterworth-Heinemann, 1975<br>Bernard Schutz: "A first course in general relativity", Cambridge, University Press, 1985<br>Robert Wald: "General Relativity", The University of Chicago Press, 1984<br>Edward W.Kolb, Michael S.Turner: "The Early Universe", Addison-Wesley, 1990 | |
| **course leader** (*name, title, acad. degree*): Gyula Bene , assoc. prof., CSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## AF-3

| | |
|---|---|
| **course title**: Gravitational-wave Astrophysics | **credits**: 3 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The course gives an introduction to the theory of gravitational waves (GWs), GW detection, and astrophysical sources of GWs. We overview the general relativistic background of GWs, the fundamentals and capabilities of interferometric GW-detectors and their noise background, and learn tools for analyzing data output of these detectors. We also study the applicability of GW-observations in understanding the physics of the GW sources. | |
| **required readings**:<br><br>**recommended readings**:<br>Peter R. Saulson: Fundamentals of Interferometric Gravitational Wave Detectors. David G. Blair: The detection of gravitational waves. Jolien D. E. Creighton, Warren G. Anderson: Gravitational-Wave Physics and Astronomy. | |
| **course leader** (*name, title, acad. degree*): Zsolt Frei, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): Peter Raffai, assistant professor, PhD | |

## AF-4

| | |
|---|---|
| **course title**: Cosmology | **credits**: 3 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Cosmology, as a scientific field, studies the physics of formation and evolution of the Universe as a whole and its various constituents. The course provides an insight into the general relativistic background of cosmology and the thermal history of the Universe, and outlines the connections of the field with particle physics. Students can learn about the most recent results, unsolved problems, and observational projects in present day precision cosmology. | |
| **required readings**:<br><br>**recommended readings**:<br>Scott Dodelson: Modern cosmology. | |
| **course leader** (*name, title, acad. degree*): Zsolt Frei, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): Peter Raffai, assistant professor, PhD | |

## AF-5

| **course title**: Nuclear and particle astrophysics | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Thermodynamics of the early universe. Particle physics background of cosmology. Cosmic inflation. Baryogenesis. Big-bang nucleosynthesis. Hydrostatic burning phases of stars, supernova explosions. Nucleosynthesis in stars and supernovae. | |
| **required readings**:<br>E. Kolb, M. Turner: The early universe<br>D. Clayton: Principles of stellar evolution and nucleosynthesis<br>C. Rolfs, W. Rodney: Cauldrons in the cosmos<br><br>**recommended readings**:<br>J. Bahcall: Neutrino astrophysics | |
| **course leader** (*name, title, acad. degree*): Attila Csótó, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**AF-6**

| **course title**: Observational methods in astrophysics | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Overview of various equipments and methods used in deriving astrophysical information from observations of different celestial objects (stars, galaxies, planets, etc.). Basic categories of astronomical observations: imaging, photometry and spectroscopy. Effects of the Earth's atmosphere on ground-based astronomical observations. Introduction to space astronomy. Observations in the entire electromagnetic spectrum, from gamma rays to radio waves. Fundamental stellar parameters and their observational determination. | |
| **required readings**:<br><br>**recommended readings**:<br>Smith, R. C. 1995, Observational Astrophysics, Cambridge Univ. Press<br>P. Léna, F. Lebrun, F. Mignard 1998, Observational Astrophysics, Springer | |
| **course leader** (*name, title, acad. degree*): László Szabados, research advisor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**AM-1**

| **course title**: Quantum chemistry I | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Methods for determining the ground state: variational principle, Eckart inequality. Method of moments. Perturbation theory, recursion formulas. Rayleigh–Schrödinger and Brillouin–Wigner method. Size consistency. Reduced resolvent. Pade-approximation. Partition method. Wave operator, Lippman–Schwinger equation. Second quantization formalism. Wick's theorem, Fermi vacuum. Electron-hole formalism. Density matrices. Fock operator. Spatial orbitals. Brillouin theorem. Many body perturbation theory. | |
| **required readings**:<br><br>**recommended readings**:<br>P. R. Surjan: Second Quantized Approach to Quantum Chemistry, Springer<br>R. McWeeny: Methods of Molecular Quantum Mechanics, 2nd Ed., Academic | |
| **course leader** (*name, title, acad. degree*): Péter Surján , professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**AM-3**

| | |
|---|---|
| **course title**: Carbon nanostructures | **credits**: 3 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Discovery of C60, historical survey, isolated cage like molecules;<br>Properties of fullerenes in gas -, liquid - and solid phases;<br>Doped fullerenes, superconductivity; fullerene polymers;<br>Preparation of single-walled and multi-walled carbon nanotubes;<br>Geometry, electronic structure and vibration properties of carbon nanotubes;<br>Applications of carbon nanotubes | |
| **required readings**:<br>Synopses of the lectures, downloadable files from the home page of the lecture<br><br>**recommended readings**:<br>M.S.Dresselhaus, G.Dresselhaus, P.C.Eklund: Science of Fullerenes and Carbon Nanotubes, Academic Press, San Diego, 1996<br>R.Saito, G.Dresselhaus, M.S.Dresselhaus: Physical Properties of Carbon Nanotubes, Imperial College Press, London, 1998<br>S.Reich, Ch.Thomsen, J.Maultzsch: Carbon Nanotubes, Basic Concepts and Physical Properties, Wiley-VCH, Berlin, 2004 | |
| **course leader** (*name, title, acad. degree*): Jenő Kürti , professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**AM-4**

| **course title**: Macromolecules | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Flexible chain polymers: polymerization polycondensation, partitition function of polymers, basic of conformational analysis, local and global conformations, cooperativity effects, statistical characterization of ideal polymer coils, theta state, rubber elasticity<br>Conjugated polymers: conjugated structures, linear chain – instabilities in one dimension, effect of doping, insulator-metal transition, solitons, polarons, bipolarons<br>Biopolymers: configuration of cellulose, investigation of the structure of proteins with calculation of the energies and with statistical methods, theoretical investigation of transmembrane proteins, structure and flexibility of DNA | |
| **required readings**:<br>Synopses of the lectures, downloadable files from the home page of the lecture<br><br>**recommended readings**:<br>M.Rubinstein, R.H.Colby: Polymer Physics, University Press, Oxford, 2003<br>S.Roth, D.Carrol: One-Dimensional Metals: Conjugated Polymers, Organic Crystals, Carbon Nanotubes, Wiley-VCH Weinheim, 2004<br>JM.Berg, JL.Tymoczko, L.Stryer: Biochemistry, W.H.Freeman and Company, 2002 | |
| **course leader** (*name, title, acad. degree*): Jenő Kürti , professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): Jenő Kürti, professor, DSc; István Simon, professor, DSc; Sándor Pekker, scientific advisor, DSc | |

**AM-5**

| | |
|---|---|
| **course title**: Many-particle physics I | **credits**: 3 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Occupation number representation<br>Finite temperature Green's function, calculation of thermodynamical quantities by the Green's function. Perturbation theory, Feynman's graphs.<br>Electron gas, Thomas-Fermi approximation, RPA (random phase approximation), correlation energy at zero temperature and in plasma, strong electrolytes, screening of charges<br>Quasiparticles, spectral function, retarded Green's function, quasiparticles in electron gas.<br>Density fluctuation propagator. Determination of collective excitations, Plasma oscillations, Landau damping in plasma. | |
| **required readings**:<br>Szirmai Gergely, Szépfalusy Péter: Soktestprobléma (lecture note in hungarian)<br>**recommended readings**:<br>L. D. Landau, E. M. Lifshitz, Statistical Physics, Part 2, Elsevier, 2013.<br>L. D. Landau, E. M. Lifshitz, Physical Kinetics, Part 2, Elsevier, 2013.<br>A. L. Fetter and J. D. Walecka: Quantum Theory of Many-Particle Systems, McGrow-Hill, New York, 1971 | |
| **course leader** (*name, title, acad. degree*): András Csordás, assoc. prof.  , DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**AM-6**

| **course title**: Many-particle physics II | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Properties of Bose gases<br>Bose-Einstein condensation (BEC)<br>Elementary excitations (Bogoliubov's canonical transformation)<br>Temperature dependence of order parameter<br>Superfluid Fermi-gases<br>Cooper phenomenon<br>Bardeen-Cooper-Scriffer (BCS) theory<br>Energy gap, critical temperature<br>BCS-BEC transition | |
| **required readings**:<br><br>**recommended readings**:<br>L. D. Landau, E. M. Lifshitz, Statistical Physics Elsevier, 2013.<br>L. Pitaevskii, S. Stringari: Bose–Einstein Condensation, Clarendon Press, Oxford, 2003<br>A. Griffin: Excitations in a Bose Condensed Liquid, Cambridge N.Y., 1993<br>A. L. Fetter, J. D. Walecka: Quantum Theory of Many-Particle Systems, McGrow-Hill, New York, 1971 | |
| **course leader** (*name, title, acad. degree*): András Csordás, assoc. prof.  , DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## AM-7

| **course title**: Quantum gases I | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Experiments with trapped ultracold bosons<br>Bose-Einstein condensation in external potential in the noninteracting model<br>Derivation and solutions of the Gross-Pitaevskii equation at zero temperature<br>Thomas-Fermi approximation for the condensate.<br>Density wave excitations for bosons, Bogoliubov equations for bosons<br>Quantum hydrodynamics for the excitations (for bosons)<br>The atomic laser<br>Vortices in quantum gases | |
| **required readings**:<br><br>**recommended readings**:<br>Landau, L.D., Lifsic, I.M., Elméleti Fizika III, Kvantummechanika Tankönyvkiadó (1978)<br>Fetter A. L., Walecka J. D., Quantum theory of many-particle systems, McGraw-Hill (1971)<br>Haken, H., Wolf, H.C., The Physics of Atoms and Quanta – Introduction to Experiments and Theory, Springer (2005)<br>M. Inguscio, S. Stringari, C. E. Wieman (szerk.), Bose-Einstein Condensation in Atomic Gases, IOS Press (1999)<br>Theory of Bose-Einstein condensation in trapped gases , F. Dalfovo, S. Giorgini, L. P. Pitaevskii, and S. Stringari, Rev. Mod. Phys. 71, 463-512 (1999) | |
| **course leader** (*name, title, acad. degree*): András Csordás, assoc. prof. , DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**AM-8**

| **course title**: Quantum gases II | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Experiments with trapped ultracold fermions<br>BCS theory for trapped atomic gases, local density approximation, Feshbach resonances, gap.<br>Universality at the Feshbach resonance.<br>Density wave excitations, Bogoliubov-De Gennes equations for fermions at zero temperature.<br>Quantum hydrodynamics for density wave modes of fermions.<br>Phenomena in periodic trap potentials. | |
| **required readings**:<br><br>**recommended readings**:<br>Theory of ultracold atomic Fermi gases,Stefano Giorgini, Lev P. Pitaevskii, and Sandro Stringari Rev. Mod. Phys. 80, 1215 (2008)<br>L D Landau,E. M. Lifshitz, Quantum Mechanics, 3rd Edition (Non-Relativistic Theory), Elsevier (2013)<br>Fetter A. L., Walecka J. D., Quantum theory of many-particle systems, McGraw-Hill (1971)<br>Haken, H., Wolf, H.C., The Physics of Atoms and Quanta – Introduction to Experiments and Theory, Springer (2005)<br>Qijin Chen, Jelena Stajic, Shina Tan, Kathryn Levin, BCS-BEC Crossover: From High Temperature Superconductors to Ultracold Superfluids, Physics Reports 412, 1-88 (2005) | |
| **course leader** (*name, title, acad. degree*): András Csordás, assoc. prof.  , DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**MN-1**

| **course title**: Few-body problem in nuclear physics | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Nucleon-nucleon interaction, phase shift analysis, three-body forces. Nuclear scattering theory, two- and three-body scattering, multichannel scattering, polology, scattering theoretic description of nuclear reactions. Bound- and resonant states of few-nucleon systems, effective interactions. Numerical methods for the description of few-body systems. Applications: three-body resonances, neutron halo states, nuclear reactions with astrophysical importance. | |
| **required readings**:<br>J.R. Taylor: Scattering theory<br>R.G. Newton: Scattering theory of waves and particles<br>W. Glockle: Quantum mechanical few-body problem<br><br>**recommended readings**:<br>http://arxiv.org/find/all/1/au:+Csoto/0/1/0/all/0/1?per_page=100 | |
| **course leader** (*name, title, acad. degree*): Attila Csótó, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**MN-2**

| **course title**: Strong interaction from quarks to atomic nuclei | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The interactions of nucleons at low energies can be successfully interpreted with momentum-dependent phenomenological potentials, also potential models based on meson exchange and also in the framework of quantum field theory. These theoretical approaches and their relation to the experimentally available informations are reviewed. The change of their accuracy is assessed when the energy of interaction is inceased and resonances do appear. Mean field approximations are introduced and discussed in detail for the nuclear matter and hadronic matter.<br>The appearance of the quark degrees of freedom is investigated in high energy nucleon-nucleon interactions. Different field theoretical models of quark confinement are introduced and applied.<br>The lowest order calculation of spin independent and spin dependent quark-quark interactions is described. A potential model of heavy quark bound states is compared to the heavy meson spectrosopy.<br>The concept of quark matter and strange matter is also introduced together with the simplest experimental signatures for their existence. Effective models of the thermal and high density quark-hadron plasma are presented.<br>As a complex application models of the structure of compact stars is modelled, the mass-radius relation is derived. | |
| **required readings**:<br>D. Perkins: Introduction to high energy physics, Cambridge University Press, 4th edition, 2000<br>D. Perkins: Particle Astrophysics, Oxford University Press, 2003<br>J.D. Walecka: Theoretical Nuclear and Subnuclear Physics, World Scientific, 2004<br>**recommended readings**:<br>A. Jakovac, A. Patkos: Resummation and Renormalisation of Effective Models of Particle Physics, Lecture Notes in Physics, Springer (in press) | |
| **course leader** (*name, title, acad. degree*): András Patkós, professor, memb. of HAS | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**MN-3**

| **course title**: Experimental methods in nuclear physics | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Overview of particle accelerators at intermediate energy: GSI, Legnaro, Ganil, MSU, RIKEN.<br>Experimental possibilities of producing radioactive ion beams, fragmentation, fission, ISOL.<br>Properties of nuclei far from stability and the corresponding detection technics: neutron halo, shell closure, complex neutron detector systems, pulse shape discrimination, particle indentification technics using semiconductor detectors.<br>Measuremet technics to determine neutron capture cross sections of short-lived nuclei.<br>Nuclear activation technics for nuclear analytics and for cross-section determination, PIXE analysis. | |
| **required readings**:<br>Glenn F. Knoll: Radiation detection and measurement. John Wiley & Sons USA 1989.<br>**recommended readings**:<br>W. R. Leo: Techniques for Nuclear and Particle Physics Experiments: A How-To Approach, Springer-Verlag Berlin, 1987<br>C.A. Bertulani, M. Hussein and G. Muenzenberg,: Physics of radioactive beams, Nova Science, Hauppage, NY, 2002, | |
| **course leader** (*name, title, acad. degree*): Ákos Horváth, assoc. prof. , PhD | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**MN-4**

| **course title**: Nuclear reactions from low to high energy | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**: During the course we learn about the current methods describing nuclear reaction from low to high energies: hydrodynamical models, time dependent Hartree-Fock approximation, random phase approximation, Vlasov dynamics, optical potential, Boltzmann–Uehling–Uhlenbeck model, description of fermionic systems, equations of state, collective excitations, relativistic kinematics and hydrodynamics, description of particle production and phase transitions in nulcear physics (multifragmentation, chiral, etc.) | |
| **required readings**:<br><br>**recommended readings**:<br>C.A Bertulani, P. Danielewicz, Introduction to Nuclear Reactions, Taylor & Francis, 2004.<br>U. Mosel, Fields, Symmetries, and Quarks, Springer, 1999<br>L. P. Csernai and D. Strottman, Relativistic Heavy Ion Physics, World Scientific | |
| **course leader** (*name, title, acad. degree*): Gábor Papp , professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**MN-5**

| **course title**: Relativistic collisions of atomic nuclei | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br><br>Models of relativistic ion collisions. Most important experimental observables. The experimental heavy-ion programs of the CERN SPS and LHC, as well as the BNL AGS and RHIC accelerator facilities. The phases of the hot and dense, strongly interacting matter. The Glauber-Gribov model, and the determination of centrality in heavy-ion collisions. The phenomenology of heavy-ion collisions: Monte Carlo models, hydrodynamical models, fireball model, coalescence model, and applications of perturbative QCD. Jets, and jet quenching phenomena. The theoretical and experimental signatures of the quark-gluon plasma. Latest results from the experiments at the LHC and RHIC accelerators. | |
| **required readings**: none<br><br>**recommended readings**:<br>L.P. Csernai: Introduction to relativistic heavy ion physics. John Wiley & Sons, Chichester, 1994<br>C.Y. Wong: Introduction to high energy heavy ion collisions, World Scientific Publishing, 1990 | |
| **course leader** (*name, title, acad. degree*): Gábor Veres, assoc. prof. , DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**MN-6**

| **course title**: Detector systems in particle and nuclear physics | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Basic operating principles of particle- and nuclear physics detectors. Important detector types: drift chambers, Cherenkov detectors, Time of Flight detectors, Time Projection Chambers, calorimeters, muon detectors, semiconductor trackers, GEMs. The interaction of particles with matter. Important experimental discoveries. Basic operating principles of particle accelerators, and various challenges. Cryotechnology and superconducting magnets, beam optics. Experiments based on cosmic radiation. Experiments with neutrinos. Large experiments based at modern particle accelerator facilities. Design of experiments and various challenges. Principles of measurement of various physics quantities. Particle identification. Basic information on electronics used in nuclear physics experiments. Hadron spectrosopy, experimental reconstruction of resonances and weakly decaying particles. Application of important statistical methods in nuclear physics. Classification of particles from the experimental point of view, their detection, lifetime, identification methods. Experimental difficulties and theoretical importance of the measurement of a few selected particles. Discussion of some of the most important discoveries in particle physics. Brief overview of the experimental methods based on nuclear physics (e.g. Mossbauer-effect) and other practical applications (medical diagnostics, therapy, nuclear energy). | |
| **required readings**:<br>W. R. Leo: Techniques for Nuclear and Particle Physics Experiments: A How-To Approach, Springer-Verlag Berlin, 1987<br><br>**recommended readings**:<br>Glenn F. Knoll: Radiation detection and measurement. John Wiley & Sons USA 1989. | |
| **course leader** (*name, title, acad. degree*): Gábor Veres, assoc. prof. , DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**BF-1**

| **course title**: Introduction to Biochemistry I. | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./tut.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Molecular bioenergetics. The structure of proteins. The function of enzymes - kinetics and energetics, enzyme mechanisms. Structural properties of nucleic acids. DNA “metabolism” - replication and repair. The molecular structure of the genetic information. Rearrangements in the genetic material. RNA metabolism - transcription, maturation and degradation. Protein metabolism - translation, post-translational modifications, transport and degradation. The regulation of enzyme quantities - regulation at the level of DNA, RNA and protein metabolism. Molecular systems biology - biological system information and molecular biotechnologies. | |
| **required readings**:<br>lecture slides<br><br>**recommended readings**:<br>Stryer et al.: Biochemistry<br>Lehninger et al.: Biochemistry | |
| **course leader** (*name, title, acad. degree*): István Venekei, assoc. prof., PhD | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## BF-2

| | |
|---|---|
| **course title**: Biophysics I | **credits**: 2 |
| course type (lect./sem./pc./lab./tut..): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Basic biological concepts, physics of molecular biological processes, intermolecular interactions, low Reynolds number hydrodynamics, diffusion, activation, solutions, chemical reactions, structure and properties of proteins and nucleic acids, biological membranes, membrane potential, transport processes, nerve signaling, biological energy conversion, sensing. | |
| **required readings**:<br><br>**recommended readings**:<br>Damjanovich, Fidy, Szöllősi: Medical Biophysics<br>Glaser: Biophysics<br>Egelman: Comprehensive Biophysics<br>Berg, Stryer, Tymoczko: Biochemistry<br>Scott et al.: Molecular Cell Biology<br>Alberts et al.: Molecular Biology of the Cell | |
| **course leader** (*name, title, acad. degree*): Imre Derényi, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**BF-3**

| **course title**: Biophysics II | **credits**: 2 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): Biophysics I | |
| **course description**:<br>Goldman-Hodgkin-Katz equation, molecular motors and pumps, redox processes, bioenergetics, oxidative phosphorylation, photosynthesis, modern biophysical methods (FRET, optical tweezers, AFM, OWLS, SPR, QCM, electrophoresis, dynamic force spectroscopy), bioinformatics, biological networks, neural networks. | |
| **required readings**:<br><br>**recommended readings**:<br>Damjanovich, Fidy, Szöllősi: Medical Biophysics<br>Glaser: Biophysics<br>Egelman: Comprehensive Biophysics<br>Nelson: Biological Physics: Energy, Information, Life<br>Flyvbjerg et al.: Physics of Biological Systems<br>Vicsek: Fluctuations and scaling in biology | |
| **course leader** (*name, title, acad. degree*): Imre Derényi , professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**BF-4**

| **course title**: Biophysical methods to study macromolecular structures | **credits**: 2 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The course covers the basic biophysical techniques used to investigate macromolecular structures: X-ray crystallography, NMR/ESR spectroscopy, mass spectroscopy, electrophoresis, and optical spectroscopy: absorption-, fluorescence-, infrared- and Raman-spectroscopy. | |
| **required readings**:<br><br>**recommended readings**:<br>Cantor Schimmel: Biophysical Chemistry, Part II. Freeman, 1980 San Francisco.<br>Gáspári Zoltán és Perczel András: A fehérjék újrafelvedezett térszerkezete. Biokémia 27:33-40 (2003)<br>Wolfgang Paul: Electromagnetic traps for charged and neutral particles. Nobel Lecture, 1989<br>John Fenn: Elecytrospray wings for molecular elephants. Nobel Lecture, 2002<br>Koichi Tanaka: The origin of macromolecule ionization by laser irradiation. Nobel Lecture, 2002 | |
| **course leader** (*name, title, acad. degree*): András Czirók, assoc. prof., PhD | |
| **teacher(s)**, if any (*name, title, acad. degree*): Bálint Szabó, assistant prof., PhD | |

## BF-5

| | |
|---|---|
| **course title**: Quantitative models in cell and developmental biology | **credits**: 3 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The course covers mechanisms – and the corresponding mathematical or computational models – underlying various cell- and developmental biological phenomena. Topics: intercellular communication through ligand/receptor pairs, intracellular signal transduction networks, EGF and MAPK signaling, stochastic (Gillespie) reaction kinetics, transcriptional oscillators, feedbacks and robust adaptation, cell motility and multi-scale models of cellular systems. | |
| **required readings**:<br>figures, program codes and calculations are available at the course web page<br><br>**recommended readings**:<br>Eric H Davidson: The regulatory genome, Academic Press 2006<br>Hiraoki Kitano: Foundations of Systems Biology, MIT Press 2001 | |
| **course leader** (*name, title, acad. degree*): András Czirók, assoc. prof., PhD | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**BF-6**

| **course title**: Statistical physics of biological systems | **credits**: 3 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Major topics: introduction to sytems exhibiting scaling, basics of fractal geometry, simple models of growing structures, percolation, self-organized criticality, bacterial colonies (microbiological background, morphological diagram, models of colony growth, synchronization in biology, integrate and fire and the Kuramoto models, networks: models of equilibrium and growing graphs, processes and modules, collective motion: basic phenomena and models, group motion of people | |
| **required readings**:<br><br>**recommended readings**:<br>T. Vicsek, ed.," Fluctuations and Scaling in Biology" (Oxford Univ. Press, Oxford) 2001<br>Philip Ball, Critical Mass: How One Thing Leads to Another (Farrar, Straus and Giroux), 2001 | |
| **course leader** (*name, title, acad. degree*): Tamás Vicsek, professor, memb. of HAS | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**KF-1**

| **course title**: Electrons in solids | **credits**: 3 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Models of interacting electron systems. Correlation and screening. Quasi particles and collective excitations. Density functional theory. Landau theory of Fermi liquid. Luttinger liquid, quantum Hall liquid. Broken-Symmetry states in interacting electron systems. Strongly correlated systems. Random systems. Mesoscopic systems. | |
| **required readings**: Jenő Sólyom: Fundamentals of the Physics of Solids: Volume 3 - Normal, Broken-Symmetry, and Correlated Systems, Springer; 2011 edition<br>**recommended readings**: Jenő Sólyom: Fundamentals of the Physics of Solids: Volume 1: Structure and Dynamics, Springer; 2007 edition, Jenő Sólyom: Fundamentals of the Physics of Solids: Volume II: Electronic Properties, Springer; 2009 edition, G. D. Mahan: Many-Particle Physics, Plenum Press, 1990 | |
| **course leader** (*name, title, acad. degree*): József Cserti, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**KF-2**

| **course title**: Experimental methods used in condensed matter physics | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Experimental methods applied in condensed matter physics (diffraction, microscopy, spectroscopy, etc.) are discussed in details. First the physical bases of the different techniques are introduced, then the different type of instruments applied recently are explained, finally several real examples are shown. | |
| **required readings**:<br>Károly Havancsák: Modern experimental methods in material science, lecture notes<br>**recommended readings**: | |
| **course leader** (*name, title, acad. degree*): István Groma, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**KF-3**

| **course title**: Materials physics I | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br><br>Thermodynamics of multicomponent systems. Lattice defects. Equilibrium and non-equilibrium phase diagrams, calculation of phase diagrams from free energy – composition functions. Ideal and regular solid solutions, factors determinig solid solubility. Diffusion in solids: mechanisms, correlation, Kirkendall-effect, Dareken-equations. Solidification, nucleation. | |
| **required readings**:<br><br>**recommended readings**:<br>R. W. Cahn. P. Haasen: Physical metallurgy, Elsevier 1996<br>J. W. Christian: The theory of transformations in metals and alloys, Pergamon 1975 | |
| **course leader** (*name, title, acad. degree*): János Lendvai, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**KF-4**

| **course title**: Materials physics II | **credits**: 3 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Precipitation from supersaturated solid solutions: stability of the initial state, sharp and continuous transformations. Nucleation and growth. Interface energy, metastable phases. Spinodal decomposition, gradient energy. Mechanisms of plastic deformation of solids. Strengthening effects. Recovery and recrystallization. Diffusion-less phase transformations: structure changes, Martensitic transformation, shape memory effect. Nanostructured materials. Ceramics. Glasses. Polymers. Composites and functionally graded materials. | |
| **required readings**:<br><br>**recommended readings**:<br>R. W. Cahn. P. Haasen: Physical metallurgy, Elsevier 1996<br>J. W. Christian: The theory of transformations in metals and alloys, Pergamon 1975 | |
| **course leader** (*name, title, acad. degree*): János Lendvai, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**KF-5**

| **course title**: Magnetism | **credits**: 3 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Origin of different magnetic properties of materials (magnetic moments, magnetic interactions (magnetostatic, exchange, super exchange, RKKY), magnetic anisotropy). Magnetic measuring techniques (induction and force based, SQUID, nuclear and optical methods). Magnetic order (ferro-, antiferro-, ferrimagnetic, non-collinear), magnetic domain structure and magnetic materials (hard- and softmagnetic materials, spinglasses, amorphous materials, superparamagnetic systems). Magnetic phenomena (surface anisotropy, exchange bias, giant magnetoresistance, quantum tunneling) in nanosystems (thin films, multilayers, granular materials). | |
| **required readings**:<br><br>**recommended readings**:<br>S. Chikazumi: Physics of Ferromagnetism<br>J. M. D. Coey: Magnetism and Magnetic materials<br>Robert C. O'Handley: Modern Magnetic Materials<br>A. P. Guimaraes: Principles of Nanomagnetism | |
| **course leader** (*name, title, acad. degree*): Sára Judit Balogh, res. advisor, Dsc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## KF-6

| **course title**: Superconductivity | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Phenomenological description of superconductivity: Ginzburg-Landau theory, Bogoljubov-de Gennes equations, vortexes. Tunneling: Josephson effect, Andreev reflection. Field theoretic description of strongly coupled superconductors. Unconventional superconductivity, phase-coherent states of low-dimensional systems. | |
| **required readings**:<br><br>**recommended readings**:<br>P.G. de Gennes: Superconductivity of Metals and Alloys (Benjamin, Menlo Park, CA 1966)<br>M. Tinkham: Introduction to Superconductivity (McGraw Hill, NY 1975) | |
| **course leader** (*name, title, acad. degree*): István Groma, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**KF-7**

| **course title**: Physics of semiconductor and electronic devices | **credits**: 3 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>The aim of the course is to provide comprehensive knowledge on the theoretical and physical basis of semiconductor devices used in modern information and communication systems.<br>*Topics:*<br>types and manufacture of semiconductors; P-N and metal–semiconductor junctions; type of diodes (tunnel, backward, varicap, Gunn, ...); BJT devices, Ebers-Moll equations; types and operation of MOS transistors; applications of semiconductors: CCD, solar cells, CPU, types of semiconductor memories (RAMs, Flashes, SSD, ...); semiconductor sensors. | |
| **required readings**:<br><br>**recommended readings**:<br>J. P. Colinge, C. A. Colinge, Physics of Semiconductor Devices (2002, Kluwer Academic Publishers)<br>Kwok K. Ng, Complete Guide to Semiconductor Devices (2002, Wiley-IEEE Press) S.M. Sze, Physics of Semiconductor Devices, (Wiley-Interscience, 1969)<br>Aldert van der Ziel, Solid State Physical Electronics (Prentice Hall, 1975) | |
| **course leader** (*name, title, acad. degree*): Zoltán Dankházi, assoc. prof, CSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## RF-1

| | |
|---|---|
| **course title**: Experimental methods in particle physics | **credits**: 2 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 1<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The importance and types of particle accelerators. Large accelerators currently in operation and planned. The principles of particle detection: types of detectors, particle momentum, mass, spin, lifetime, magnetic moment measurements. Various distributions, Dalitz plot. The use of computers in experimental particle physics. | |
| **required readings**:<br><br>**recommended readings**:<br>D.H. Perkins: Introduction to High Energy Physics (Addison-Wesley 1987),<br>R.N. Cahn, G. Goldhaber: Experimental Foundations of Particle Physics (Cambridge University Press 1989) | |
| **course leader** (*name, title, acad. degree*): György Vesztergombi, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**RF-2**

| **course title**: Strong interaction at low energies | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Pion-nucleon interaction, resonances, dispersion relations, current algebra, weak end electromagnetic currents, chiral symmetry, Goldston's theorem, the pion as a Goldstone boson, relations between quark and meson masses, effective Lagrangeans, sigma model | |
| **required readings**:<br><br>**recommended readings**: T.P. Cheng, L.F. Li: Gauge theory of elementary particle physics (Oxford Univ. Press 1988)<br>M. Peskin, D. Schröder: Introduction to Quantum Field Theory (Addison-Wesley 1995)<br>C. Itzykson, J.B. Zuber: Quantum Field Theory (McGraw-Hill 1980) | |
| **course leader** (*name, title, acad. degree*): Ferenc Csikor, professor, Dsc, László Palla, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**RF-3**

| **course title**: Relativistic quantum electrodynamics I | **credits**: 4 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 3<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**: Canonical quantization. General theory of symmetries, space-time symmetries. Quantum theory of free scalar, fermion, photon and vector fields. Interaction Lagrangeans. Interaction picture, LSZ reduction, S matrix. Transition probability and cross section. Wick's theorem and Feynman diagrams. Examples for the calculation of specific processes. Functional integral formalism. Non-abelian gauge theories. | |
| **required readings**:<br><br>**recommended readings**: M. Kaku: Quantum Field Theory, a Modern Introduction (Oxford Univ. Press 1993)<br>S. Weinberg: The Quantum Theory of Fields I, II (Cambridge Univ. Press 1995) | |
| **course leader** (*name, title, acad. degree*): Ferenc Csikor, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## RF-4

| **course title**: Relativistic quantum electrodynamics II | **credits**: 2 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 1<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**: Scattering theory in quantum field theory. N point Green functions and perturbative evaluation. Feynman-diagrams and their evaluation in quantum electrodynamics. Calculation of the simplest divergent diagrams and regularization with the Pauli-Villars method: vacuum polarization, the electron self-energyand vertex. The renormalization method. Determination of the renormalized charge, electron mass and the wave function renormalization constant. Role of the Ward identity. Power counting. Classification of quantum field theories as renormalizable, super-renormalizable and non-renormalizable theories. | |
| **required readings**:<br>A. Akhiezer and V.B. Beresteckii: Quantum Electrodynamics<br><br>**recommended readings**:<br>C. Itzykson and J.B. Zuber: Quantum Field Theory, McGraw-Hill, New York 1980 | |
| **course leader** (*name, title, acad. degree*): Ferenc Csikor, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**RF-5**

| **course title**: Weak interaction | **credits**: 4 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 3<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Historical review, conserved quantum numbers and selection rules, muon decay, strangeness conserving semi leptonic processes, beta decay, conserved vector current, axial form factors, semi leptonic decays of kaons and hyperons, non leptonic kaon decays and the neutral K meson, GIM mechanism, tau lepton b quark and the flavour families, the KM matrix, the limits of current current theory, spontaneous symmetry breaking and the Higgs mechanism, the bosonic and fermionic sectors of the SW model, the foundations of grand unification | |
| **required readings**:<br>L.B. Okun: Lepton and quarks (North Holland, 1984)<br>T.P. Cheng and L.F. Li: Gauge theory of elementary particle physics (Oxford Univ. Press, 1988)<br>W. Greiner, B. Müller: Gauge theory of weak interactions (Springer, 1993)<br><br>**recommended readings**: | |
| **course leader** (*name, title, acad. degree*): Palla László, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**RF-6**

| **course title**: Quantum chromodynamics | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**: History of QCD. Lagrange-density, quantization, renormalization, renormalization group equations. Asymptotic freedom and asymptotic behaviour of Green functions. Electron-positron annihilation into hadrons, jet physics. Deeply inelastic scattering. QCD description of hard processes. | |
| **required readings**:<br><br>**recommended readings**: T. Muta: Foundations of Quantum Chromodynamics (Word Sci. 1987)<br>W. Greiner, A. Schafer: Quantum Chromodynamics (Springer 1994) | |
| **course leader** (*name, title, acad. degree*): Ferenc Csikor, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## SK-1

| | |
| --- | --- |
| **course title**: Nonlinear dynamics and chaos | **credits**: 3 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The different types of dynamical systems, nonlinearity, examples from physics, chemistry, biology and engineering, respectively. One dimensional maps, dynamics on the circle, nonlinear oscillators, damped pendulums, Josephson junctions in superconductivity. Two-dimensional dynamics, Poincaré-crosssection, classifications of linear systems, linearization around the fixed points, conservative and reversible systems, index theorems. Limit cycles: Poincaré-Bendixson theorem, relaxations in oscillations. Classification of bifurcations, catastrophes. Chaos: Lorenz-equations, strange attractors, chaos in one dimensional maps, Lyapunov exponents, universality, fractal dimensions, multifractal descriptions. | |
| **required readings**:<br>Tamás Tél, Márton Gruiz, Chaotic Dynamics: An Introduction Based on Classical Mechanics, Cambridge University Press, 2006.<br>**recommended readings**:<br>Steven Srogatz: Nonlinear Dynamics and Chaos (Perseus Books Group) | |
| **course leader** (*name, title, acad. degree*): András Csordás, assoc. prof., DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**SK-2**

| **course title**: Nonequilibrium statistical physics | **credits**: 3 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Theory of linear response: Correlation and response functions. Analytic properties, excitations. Classical limit. Dissipation. Fluctuation-dissipation theorem. Consequences of microscopic time reversibility symmetry. Transport processes: electronic conductivity. Cross section in neutron scattering. Characterization of stochastic processes, Marcov-processes. Diffusive processes: Fokker-Planck equation, stochastic differential equations. Applications in physics: Brownian motion, hydrodynamic fluctuations, Onsager relations. Jump processes: Master equation. Stability of the stationary distribution, H-theorem. Basics of the Monte Carlo method. The Boltzmann equation. Relaxation time approximation. Applications in physics. | |
| **required readings**:<br><br>**recommended readings**:<br>Robert Zwanzig: Nonequilibrium Statistical Mechanics, Oxford University Press 2001<br>W. Brenig: Statistical theory of heat – Nonequilibrium phenomena, Springer Verlag, 1989. | |
| **course leader** (*name, title, acad. degree*): Gábor Vattay, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**SK-3**

| **course title**: Phase transitions | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Stability of thermodynamic state: coexistences and transitions of different phases, symmetry breaking, classifications. Overview of phase transitions in condensed matter physics. Critical exponents.<br>Models of phase transitions. Exact results. Long range order correlations in symmetry breaking states of isotropic systems.<br>Classical theories and their critics: Landau theory, mean-field approximation.<br>High temperature series.<br>Scaling hypothesis and its consequences<br>Renormalization group transformation and its connection with critical behaviors: fixed point, scaling, universality.<br>Construction of the transformation in real- and in k-space respectively. Overview of the results.<br>Dynamical critical phenomena: conventional theory, dynamical critical scaling, examples. | |
| **required readings**:<br><br>**recommended readings**:<br>P.M. Chaikin, T.C. Lubensky: Principles of condensed matter physics, Cambridge University Press, 1995.<br>J. Cardy: Scaling and Renormalization in Statistical Physics, Cambridge University Press, 1996. | |
| **course leader** (*name, title, acad. degree*): András Csordás, assoc. prof., DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## SK-4

| | |
|---|---|
| **course title**: Computer simulations of complex systems | **credits**: 3 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Complex systems in general. Simulating and analysing omplex networks. Generating Erdős-Rényi graphs, small world and scale free networks. Algorithms for degree distributions, graph diameter, percolation, adjacency matrix spectrum, cliques. Robustness of graphs. Simulating chaotic dynamics, measuring Lyapunov exponent and dimension of strange attractor. Cellular automata. Neural networks, Hopfield model, perceptron. | |
| **required readings**:<br>Claudius Gros: Complex and Adaptive Dynamcial Systems, Springer; 1st ed.2008. Corr. 2nd printing edition (July 1, 2009)<br>**recommended readings**: | |
| **course leader** (*name, title, acad. degree*): István Csabai, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): László Dobos, assistant professor, PhD | |

## SK-5

| | |
| --- | --- |
| **course title**: Physics of environmental flows | **credits**: 3 |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Effects of Earth's rotation (Coriolis and centrifugal forces), Navier-Stokes equation in rotating reference frames, dimensionless form of equations, Rossby number, Froude number, dynamical pressure, geostrophic equilibrium, Taylor-Proudman theorem, linearization of the equations, wave phenomena in rotating fluids, shallow water equations, conservation of potential vorticity, effects of surface curvature, Ekman boundary layers, effects of density stratification, thermal wind, Boussinesq approximation, baroclinic instability. | |
| **required readings**:<br>Benoit Cushman-Roisin: Introduction to Geophysical Fluid Dynamics. Prentice Hall, 1994.<br>**recommended readings**:<br>Geoffrey K. Vallis: Atmospheric and Oceanic Fluid Dynamics: Fundamentals and Large-scale Circulation. Cambridge University Press, 2006.<br>Jorg Imberger: Environmental Fluid Dynamics. Academic Press, 2012. | |
| **course leader** (*name, title, acad. degree*): Imre M. Jánosi, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## SK-6

| **course title**: Nonequilibrium transport in nanosystems | **credits**: 3 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Introduction to nanophysics.Relation between the scattering matrix and the Landauer-Buttiker formula, the transfer matrix and the Green's function approach. Ballistic and diffusive transport, the Ohm's law in nanostructure,  Aharonov–Bohm effect, quantum Hall effect, weak localization, universal conductance fluctuation, spintronics, graphene. | |
| **required readings**: S. Datta: Electronic Transport in Mesoscopic Systems, Cambridge University Press, Cambridge, 1995<br><br>**recommended readings**: D. K. Ferry and S. M. Goodnick: Transport in Nanostructures, (Cambridge University Press, Cambridge, 1997), T. Heinzel: Mesoscopic Electronics in Solid State Nanostructures, (Wiley-VCH GmbH & Co. KGaA, Weinheim, 2003). | |
| **course leader** (*name, title, acad. degree*): József Cserti , professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## SK-7

| **course title**: Fractal growth phenomena | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Major topics: Fractals in nature, fractal dimension, types of fractals (isotropic, self-ffine and fat), multifractals, cluster models of fractal growth, percolation, random walks, diffusion-limited aggregation: its simulation, theoretical treatment and multifractal features, growth of self-affine surfaces, role of fluctuations, related equation, role of surface tension, continuum description of fractal growth, overview of related experiments | |
| **required readings**:<br><br>**recommended readings**:<br>Fractal growth phenomena, Tamas Vicsek, World Scientific, 1992<br>Techniques of fractal geometry, Kenneth Falconer, Wiley, 1997 | |
| **course leader** (*name, title, acad. degree*): Tamás Vicsek, professor, memb. of HAS | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**SK-8**

| **course title**: Econophysics | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>Extreme statistics, Fischer-Tippet theorem and applications in risk assessment;<br>Central limit theorem, stable distributions, attraction pools, centrality and norm constant choices, speed of convergence, large deviations;<br>Random matrices, Wigner surmise, Wishart matrices, Marchenko-Pastur theorem.<br>Multivariate distributions, copulae. Price fluctuations on real markets, empirical stylization, non-stationary behavior (ARCH-GARCH models). Portolio and risk measures: elliptical distributions, portfolio optimization, value-at-risk, variance as risk measure, absolute deviation, expected shortfall, maximal loss, coherent and spectral measures. Financial regulation examples (Basel I, II and III, order book regulations). Instability of portfolio optimization, divergence of estimation error, fluctuating weights, noise reduction (cleaning), simulated markets, Cholesky decomposition. Derivatives (forward, swap, options) and their pricing methods, Black-Scholes formula, interpretation of the smile curve, remaining risk. | |
| **required readings**:<br><br>**recommended readings**:<br>J.-Ph. Bouchaud és M. Potters: Theory of Financial Risks, Cambridge University Press, 2000<br>R.N. Mantegna és H.E. Stanley: An Introduction to Econophysics – Correlations and Complexity in Finance, Cambridge University Press, 2000 | |
| **course leader** (*name, title, acad. degree*): Gábor Papp, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## IF-1

| **course title**: Modern numerical methods in physics | **credits**: 4 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The aim is to introduce students to advanced numerical methods applied in physicists' research practice.<br>Syllabus: Linear systems, eigenvalue problems, singular value decomposition. Sparse matrices. Numerical integration, Monte Carlo methods. Numerical solution of ordinary differential equations, Runge-Kutta and Bulirsch-Stoer methods, adaptive stepsize control. Conservative and stiff equations. Two point boundary value problems: shooting and relaxation methods. Numerical solution of partial differential equations. von Neumann stability analysis. Finite difference, finite volume, finite element methods. Spectral methods. Multigrid methods. | |
| **required readings**:<br><br>**recommended readings**:<br>William H. Press, Brian P. Flannery, Saul A. Teukolsky, William T. Vetterling: Numerical Recipes in C: The Art of Scientific Computing, Cambridge University Press, 2002.<br>John P. Boyd: Chebyshev and Fourier Spectral Methods, Dover, New York, 2001.<br>http://www.netlib.org/lapack | |
| **course leader** (*name, title, acad. degree*): Gyula Bene, assoc. prof., CSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**IF-2**

| **course title**: Data mining in physics | **credits**: 4 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 3<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>During the course the students get acquainted with modern methods of analyzing large data sets and learn to perform such analysis. This is the introductory of a series of lectures, where time series analysis, principal component analysis, exploration of correlations, noise, artificial intelligence, databases, signal processing, cluster detection, classification and optimization are studied. | |
| **required readings**:<br><br>**recommended readings**:<br>Berry, M., J., A., & Linoff, G., S., (2000). Mastering data mining. New York: Wiley.<br>Edelstein, H., A. (1999). Introduction to data mining and knowledge discovery (3rd ed). Potomac, MD: Two Crows Corp.<br>Han, J., Kamber, M. (2000). Data mining: Concepts and Techniques. New York: Morgan-Kaufman.<br>Westphal, C., Blaxton, T. (1998). Data mining solutions. New York: Wiley.<br>www.crisp-dm.org<br>Hastie, T., Tibshirani, R., & Friedman, J. H. (2001). The elements of statistical learning: Data mining, inference, and prediction. New York: Springer.<br>Pregibon, D. (1997). Data Mining. Statistical Computing and Graphics, 7, 8.<br>Witten, I. H., & Frank, E. (2000). Data mining. New York: Morgan-Kaufmann.<br>Fayyad, U. M., Piatetsky-Shapiro, G., Smyth, P., & Uthurusamy, R. (1996). Advances in knowledge discovery & data mining. Cambridge, MA: MIT Press.<br>Weiss, S. M., & Indurkhya, N. (1997). Predictive data mining: A practical guide. New York: Morgan-Kaufman. | |
| **course leader** (*name, title, acad. degree*): Gábor Papp, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**IF-3**

| **course title**: Models of infocommunication networks | **credits**: 4 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect., pc.<br>number of hours per week: 2+1<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>History of communication networks (telephone, Internet) and main technologies. Topology of networks: Internet AS and router level topology, Erdos-Renyi random networks, Barabasi-Albert scale-free networks, measurement of network topology. Traffic in networks: Erlang formuli, long range correlations, multifractal traffic models, on-off processes, Hurst-exponents. Microscopic description: basic concepts of queueing, M/G/1 queue, fluid model, diffusion model, available bandwidth, delay and available bandwidth measurements. Traffic control in TCP/IP: congestion window, stochastic models, 1 over sqrt(p) rule, mean field approximation, Network Simulator. The future of the Internet: peer-to-peer systems, wireless Internet, the PlanetLab | |
| **required readings**:<br><br>**recommended readings**:<br>M. Crovella: Internet Measurements (2006)<br>L. Kocarev – G. Vattay: Complex Dynamics in Communication Networks (Springer 2005) | |
| **course leader** (*name, title, acad. degree*): Gábor Vattay, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**IF-5**

| **course title**: Physical principles of informatics | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The course aims to provide knowledge on the functioning principles and physical fundamentals used in modern information and communication technologies.<br>*Topics:*<br>electromagnetic waves in conductors and dielectrics; wave optics; wired, wireless and optical transmission; magnetic properties, MR, AMR, GMR, spin valve systems; magnetic and optical data storage; micromechanics, MEMS; fundamentals of quantum computers. | |
| **required readings**:<br><br>**recommended readings**:<br>K. Simonyi, Foundations of Electrical Engineering (Pergamon Press, Oxfprd, 1963)<br>A. S. Tanenbaum, D. J. Wetherall, Computer Networks (Pearson; 5th edition, 2010)<br>A. Nussbaum, R. A. Phillips, Contemporary optics for scientists and engineers (Prentice-Hall, 1976)<br>D.C. Ralph, M.D.Stiles, SpinTransferTorques, J.Magn.Magn.Mater. 320 (2008) 1190 | |
| **course leader** (*name, title, acad. degree*): Zoltán Dankházi, assoc. prof., CSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**IF-6**

| **course title**: Visualization | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The aim of the course is to present methods used in natural sciences to visualize information, including algorithms, programming techniques and available software packages. How to prepare 2D graphics, graphs and 3D illustration based on available data. Short introduction to the IDL and MatLab programming language. Programming in OpenGL and DirectX. Software and hardware background of stereoscopic and volumetric 3D visualization. | |
| **required readings**:<br>Ware: Information Visualization, Morgan Kaufmann, 2004<br>Bonneau and Nielson: Scientific Visulaization, Springer, 2006<br><br>**recommended readings**:<br>- | |
| **course leader** (*name, title, acad. degree*): Zsolt Frei, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## IF-7

| **course title**: Modeling of physics with computers | **credits**: 3 |
| --- | --- |
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 3<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): pcm. | |
| semester: 3 | |
| prerequisites (if any): Computer simulations in physics (A-2) | |
| **course description**:<br>The goal of this computer lab is to give hands-on experience and to try in practice the methods learned during the “Computer simulations in physics” course. Students install, configure and run state-of-art physics simulation software, visualize and analyze the results, compare them to result found in scientific papers. Examples: Cosmological N-body simulations with Gadget2. Hydrodynamics simulations using OpenFOAM. Molecular dynamics with the HOOMD-blue package. | |
| **required readings**:<br>V. Springel: The cosmological simulation code GADGET-2, Mon. Not. R. Astron. Soc. 364, 1105–1134 (2005)<br>Piet Hut and Jun Makino: An Introduction to the N-Body Problem with computer simulation codes in C++, http://www.artcompsci.org/msa/web/index.html<br>Hrvoje Jasak, Aleksandar Jemcov, Zeljko Tukovic: OpenFOAM: A C++ Library for Complex Physics Simulations, International Workshop on Coupled Methods in Numerical Dynamics IUC, Dubrovnik, Croatia, September 19th-21st 2007<br>**recommended readings**:<br>Introduction to Computer Simulation Methods by H. Gould and J. Tobochnik, (Addison-Wesley, 1996) | |
| **course leader** (*name, title, acad. degree*): István Csabai, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): László Dobos, assistant professor, PhD | |

## IF-8

| **course title**: Scientific programming of graphical processors | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The aim of the course is to provide the students with basic knowledge in the field of performance-oriented, parallel programing. During the course the students will be familiar with the modern hardware architectures (CPU, GPU, APU) and the abstract realization of those. Using the abstract realizations an introduction and practical usage information to the present and planned parallel computational libraries and APIs, such as MPI, OpenCL, C++AMP and SYCL will be given.<br>The course builds on a basic knowledge of C/C++ from the audience, since the tools presented are based on C/C++. | |
| **required readings**:<br><br>**recommended readings**:<br>1. The C++ Programming Language (4th Edition), Bjarne Stroustrup, Addison-Wesley ISBN 978-0321563842, 2013.<br>2. Effective Modern C++, Scott Meyers, O'Reilly Media, 2014.<br>3. The OpenCL Programming Book - Ryoji Tsuchiyama, et. al, Fixstars, 2010, http://www.fixstars.com/en/opencl/book/OpenCLProgrammingBook/contents/ | |
| **course leader** (*name, title, acad. degree*): István Csabai, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

## IF-9

| **course title**: Scientific programming of graphical processors 2 | **credits**: 3 |
|---|---|
| course type (lect./sem./pc./lab./cons.): lect.<br>number of hours per week: 2<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): exam | |
| semester: 3 | |
| prerequisites (if any): | |
| **course description**:<br>The aim of the course is to promote the students practical knowledge in programing graphical processors at advanced level and map the area of applicability:<br>basis of functional programing, the functional building blocks, the functional structure and implementation of vector-matrix operations, solution of ordinary differential equations, classical N-body simulations, statistical physical simulations (Ising model), Monte-Carlo simulations, solution of partial differential equations. | |
| **required readings**:<br><br>**recommended readings**:<br>1. The C++ Programming Language (4th Edition), Bjarne Stroustrup, Addison-Wesley ISBN 978-0321563842, 2013.<br>2. Effective Modern C++, Scott Meyers, O'Reilly Media, 2014.<br>3. The OpenCL Programming Book - Ryoji Tsuchiyama, et. al, Fixstars, 2010, http://www.fixstars.com/en/opencl/book/OpenCLProgrammingBook/contents/<br>4. Numerical Recipes 3. kiadás, Cambridge University Press, 2013, ISBN-10: 0521880688<br>5. Chebyshev and Fourier Spectral Methods, John P. Boyd, Second edition, Dover, New York (2001). | |
| **course leader** (*name, title, acad. degree*): István Csabai, professor, DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**HL-1**

| **course title**: Atomic and molecular physics - Biophysics | **credits**: 7 |
|---|---|
| course type (lect./sem./pc./lab./tut.): lab.<br>number of hours per week: 5<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): pcm. | |
| semester: 2 | |
| prerequisites (if any): | |

**course description**:
The laboratory helps to acquire practice in atomic, molecular and biophysics. Students can choose from the measurements listed below. They have to complete only four measurements in the semester allowing them to deepen their knowledge in the specific field.

1. Computer simulations of molecules
2. Investigation of the electron structure of carbon nanotubes with absorption and fluorescent spectroscopy
3. Laser cooling
4. Electron spin resonance spectroscopy
5. Nuclear magnetic resonance spectroscopy
6. Raman microscopy
7. Room temperature phosphorescence and pressure-dependent fluorescence spectroscopy of enzymes
8. Investigation of the mass, size and conformation stability of biological macromolecules
9. Analysis of chemical elements by detecting the X-rays induced by accelerated particles
10. Investigation of the primary processes in photosynthesis
11. Optical manipulations and microfluidics
12. Video-polarimetry with biological applications
13. Time-lapse imaging of cell cultures

**required readings**: specific description of each laboratory measurement to be completed

**recommended readings**: Malcolm H. Levitt: Spin Dynamics: Basics of Nuclear Magnetic Resonance, Wiley, 2008. www.microscopyu.com,

**course leader** (*name, title, acad. degree*): Bálint Szabó, assist. prof., PhD

**teacher(s)**, if any (*name, title, acad. degree*): Gábor Horváth, assoc. prof., doctor of the Hung. Acad. Sci, János Koltai, assist. prof., PhD, János Rohonczy, assoc. prof., PhD, Bálint Szabó, assist. prof., PhD

## HL-2

| **course title**: Particle physics, nuclear physics and astrophysics | **credits**: 7 |
|---|---|
| course type (lect./sem./pc./lab./tut.): lab.<br>number of hours per week: 5<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): pcm. | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>This laboratory is aiming to provide those students who are specialising in particle, nuclear or astrophysics with experience in experimental methods. The goal is to study these experimental methods more deeply, and thus the students will choose, according to their interest, only a small number of experiments, but they will spend more time and much more of their own independent effort and research on those, than at a usual laboratory course. These exercises include the following topics: Cherenkov radiation, various nuclear physics experiments with scintillators and gas detectors, measurement of the thermal neutron flux and diffusion length, parameters of late neutrons at nuclear reactors, neutron value and cavity effect at nuclear reactors, exercise to operate a nuclear reactor, criticality exercise and study of nuclear reactor runaway, nuclear analytics, advanced Mossbauer spectroscopy, manipulation of atoms with lasers, astrophysical observational and image processing exerises, study of magneto-hydrodynamical waves. | |
| **required readings**:<br>The leaders of each exercise and the course leader will provide personalized and up to date reading material for each student according to their chosen exercises in the beginning of the semester. Each student is only participating in a few exercises, thus we do not specify here a required reading that would be obligatory for everyone.<br><br>**recommended readings**:<br>None | |
| **course leader** (*name, title, acad. degree*): Gábor Veres, assoc. prof., DSc | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |

**HL-3**

| **course title**: Complex systems | **credits**: 7 |
|---|---|
| course type (lect./sem./pc./lab./tut.): lab.<br>number of hours per week: 5<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): pcm. | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>Investigation of flows with PIV (Particle Image Velocimetry) method. Internal waves formed inside stratified fluid. Baroclinal rotation instability, cyclonic and anticyclonic eddies. Diffusion phenomena inside layered medium. Liquid -congested phase transition in computer networks, fundamental diagram measurement. Anomalous diffusion of internet traffic: self-affine beahviour, 1/f noise, long-term correlation, anomalous diffusion. Chaotic circuit based on the Chua circuit. Non-linear dynamics of water droplets. Phase space measurements of the double pendulum. Two-dimensional turbulence in quasi-two-dimensional layers. | |
| **required readings**:<br><br>The students carries out only part of the measurements, based on the availability of the equipments and lecturers. Therefore it is not practical to give obligatory literature for everyone. The lecturers will hand out the necessary actual literature at the beginning of the semester.<br><br>**recommended readings**:<br>Am J. Phys 61, 11 (1993)<br>Phys Rev. Lett. 85, 5332, (2000)<br>Phys Rev. Lett. 50, 346, (1983)<br>Frequenz, 46, 66, (1992)<br>Int. J. of Phsychophysiology, 24, 189 (1996) | |
| **course leader** (*name, title, acad. degree*): Zsolt Bagoly, assoc. prof., PhD | |
| **teacher(s)**, if any (*name, title, acad. degree*): Zsolt Bagoly PhD, József Stéger PhD, Imre Jánosi PhD | |

**HL-4**

| **course title**: Solid state physics and materials science | **credits**: 7 |
|---|---|
| course type (lect./sem./pc./lab./tut.): lab.<br>number of hours per week: 5<br>course language: Hungarian, English | |
| type of assessment (exam/pcm./other): pcm. | |
| semester: 2 | |
| prerequisites (if any): | |
| **course description**:<br>The aim of this subject is giving experimental experiences to help those students, who intend to realize their study in the field of solid state physics and/or materials science. By taking this lab, the students will have opportunity to know and to learn different actual research areas and/or basic experimental methods in more details. During the semester, depending on the available possibilities the students have to choose and carry out 3 complex measurements in different topics. Each measurement – one topic – takes four weeks with 5 hour work per week in the lab and self-sufficient work at home, including also the preparation of topic-report.. The measurements may be in the following topics:<br>High resolution bicrystal diffractometria, precipitation phase transition, scaling mechanical properties of solid materials, microstructural investigation of nanocrytal materials, physical characteristics of semiconductors, nuclear magnetic resonance (NMR), preparation and crystallization of metal glasses, investigation of fluid-crystals, Josephson effect, interacting electron systems, quantum Hall-effect, Mössbauer spectroscopy, scanning electron microscopy and focused ion beam (SEM/FIB), preparation of thin layers and their investigation by transmission electron microscopy (TEM). | |
| **required readings**: will be given by the leader of the actual measurement at least one week before the lab.<br><br>**recommended readings**: | |
| **course leader** (*name, title, acad. degree*): Nguyen Quang Chinh, assoc. prof., PhD | |
| **teacher(s)**, if any (*name, title, acad. degree*): | |