**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Research laboratory works I*** |
|  | Physics and astronomy |
| ***Credits*** | 6 |
| ***Total Number of Contact Hours*** | 74 |
| ***Number of Lecture Hours*** | 2 |
| ***Number of Seminar and Practical Assignment Hours*** | 0 |
| ***Number of Laboratory Work Hours*** | 72 |
| ***Independent Study Hours*** | 166 |
| ***Course Approval Date*** | 17.03.2021 |
| ***Course Developer*** | Dr.phys. Guntars Kitenbergs |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to promote a diverse research experience by carrying out short lab works that imitate scientific processes and provide knowledge and insights about the diverse research of physics within the laboratories and innovative companies.  Tasks of the course are to:   1. choose and perform laboratory works offered by research institutions and innovative companies on their respective topics. 2. know and use different research methods, to obtain, process and interpret results. 3. prepare a short protocol for each laboratory work and defend it by the scientist responsible for the particular laboratory work. 4. prepare a brief in-depth presentation on the topic of one of the laboratory works performed.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Knows selected topics in physics and astronomy (MN2, MN3), their applicability in interdisciplinary topics (MN8) and understands qualitatively development of these topics (MN4);   Skills:   1. Performs some research steps individually and in a group, is able to usescientific literature, communicates with colleagues (MV3, MV4, MV6); 2. Approaches complex phenomena research in an analytic way and uses various IT skills in getting, processing and interpreting data (MV2, MV5); 3. Follows work safety and research integrity principles, understands the limits of own knowledge (MV8);   Competence:   1. Solves physical problems, using necessary approximations (MN7.1., MV1); 2. Performs experiments, choosing an appropriate data analysis method, error estimation and comparison with models (MN7.2.). | |
| ***Course Plan*** | |
| 1. Introduction. Laboratory work list. Safety measures. Course criteria. Recommendations on performing laboratory work. Research integrity. L2 2. Laboratory work. Ld72   L – lecture, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| In this course students alone, in pairs or small groups have to continue working on processing, analyzing and summarizing labwork in a short report. In the beginning of the course students will be introduced to principles of performing labwork. Consultations (both remote and in person) will be available from course and labwork responsibles. | |
| ***Requirements for Awarding Credits*** | |
| Interim examination:   1. Laboratory work, preparation of reports and oral defense (number of works depends on the laboratory work selection) - 90%     Final examination:   1. Exam (oral presentation on a selected laboratory work) - 10%     Students are let to the final examination only if all interim examinations are passed. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Defenses of laboratory work | + | + | + | + | + | + | | 1. Exam (oral presentation) | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Alfredo, K. Hart, H. “The University and the Responsible Conduct of Research: Who is Responsible for What?”, Science and Engineering Ethics, 17 (3), 447 (2011) - doi.org/10.1007/s11948-010-9217-3 2. Reviews of Modern Physics: https://journals.aps.org/rmp/ | |
| ***Further Reading List*** | |
| 1. Reports on Progress in Physics - http://iopscience.iop.org/journal/0034-4885 2. Whitbeck, C. “Trust and the Future of Research”, Physics Today, 57 (11), 48 (2017) - https://physicstoday.scitation.org/doi/10.1063/1.1839377 | |
| ***Periodicals and other sources*** | |
| 1. Distribution service and an open-access archive for scholarly articles - arXiv.org 2. Physical Review journals - https://journals.aps.org/ | |
| ***Course Content*** |  |
| 1. **Introduction.**   **Offer of laboratory works and their selection. Safety instructions. Course requirements. Recommendations for work execution. Ethics of research work.**  Introduction to course, proposed laboratory works, course organization and assignments. Safety instructions, recommendations for the execution of works and ethical issues of research work.  **2. Laboratory works.**  Students choose lab work from the proposed list. Each work has a description available in the e-study environment, including the information of the responsible scientist, the time for work execution, consultations and defense, as well as other essential information. Students agree with the responsible scientist on the work execution schedule, taking into account the availability and capacity of the laboratories. Before development, students prepare for work using the work description and the literature shown in it. The development of works takes place in pairs or larger groups, if the nature of the work requires it. For each work, students prepare a protocol, for which a substantial individual study time is allocated. Once the protocol is prepared, students defend it to the responsible scientist.  **3. Seminars on selected laboratory works**  Each student chooses one of the executed lab works and prepares a brief presentation on the nature of the work, the methods used, the results and the future research challenges in that topic. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Fundamentals of Physics specialisations*** |
|  | Physics and astronomy |
| ***Credits*** | 8 |
| ***Total Number of Contact Hours*** | 128 |
| ***Number of Lecture Hours*** | 83 |
| ***Number of Seminar and Practical Assignment Hours*** | 45 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 320 |
| ***Course Approval Date*** | 17.04.2020 |
| ***Course Developer*** | Dr.habil.phys. Mārcis Auziņš  Dr.phys. Anatolijs Šarakovskis  Dr.phys. Jānis Cīmurs  Mg.phys. Ģirts Zāģeris |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the study course is to provide physics master students a possibility to gain an essential theoretical knowledge necessary for specialisation courses in theoretical physics, physics of continuous media, physics of the interaction of light with matter and material physics.  Tasks of the course are to:   1. Foster learning of frequently used methods for problem solving in physics; 2. Explain the mathematical formalism typical to physics specializations listed at the aim of the course; 3. Master an application of mathematical formalism to physical problems; 4. Develop an ability to choose appropriate method to solve the problem; 5. To train skills for qualitative and quantitative characterization of physical processes; 6. To explain the basic properties that characterize the behaviour of materials; 7. To train an ability to select appropriate type of material for specific application.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains non-dimensionalization and transformations of physical quantity in theoretical physics; 2. Describes mathematical models of continuum mechanics and their relevance to specific physical processes; 3. Demonstrates knowledge about methods and approaches to the atomic state description in quantum mechanics; 4. Names different technologies of synthesis and applicability of different materials;   Skills:   1. Formulates physics situation by creating mathematical models and using necessary approximations; 2. Solves mathematical problem using given methods; 3. Illustrates and interprets obtained results; 4. Analyses and describes atom interaction with light at the presence of external magnetic and/or electric fields for real situations that one faces in a research laboratory; 5. Applies the laws from different branches of physics to define characteristic properties of different materials;   Competence:   1. Identifies main factors in physical problem and modifies mathematical model to better fit physical situation when obtained result does not match experiment,; 2. Solves physical problems (problem construction, mathematical formulation, determination of important factors); 3. Understands different quantum technologies such as quantum sensors, memory elements of quantum computers and similar that uses atom - light interaction in its basis; 4. Foresees physical properties of different materials in specific physical circumstances. | |
| ***Course Plan*** | |
| 1. **Elements of theoretical physics**    1. Non-dimensionalization. L4, P4    2. General curve. L4, P4    3. Fourier series. L2, P2    4. Transformations. L6, P6 2. **Mechanics of continuum media, introduction**    1. Introduction. L2    2. Matrix formalism for solids. L6    3. Exercise problems about matrix formalism. P4    4. Differential equation formalism for solids. L4    5. Exercise problems about differential equation formalism. P4    6. Introduction in hydrodynamics. L4    7. Exercise problems about the Navier-Stokes equation and its approximations. P4    8. Turbulent flows, CFD L4 3. **Atom - light interaction**    1. Atomic states. L6    2. Introduction into the quantum angular momentum theory. L4    3. Polarization of light. L6    4. Atomic transitions - selection rules. L6    5. Coherent superposition of atomic states. L4    6. Atoms in external fields. L6 4. **Basics of materials physics**    1. Introduction to materials physics. L2    2. Atomic structure and interatomic bonding. L1, P1    3. Structure of crystalline materials. L1, P1    4. Defects in materials. L1, P1    5. Phase diagrams. L1, P1    6. Metals and alloys. L1, P1    7. Ceramics and glasses. L1, P1    8. Test. P2    9. Polymers. L1, P1    10. Composites. L1, P1    11. Semiconductors. L1, P1    12. Mechanical properties of materials. L1, P1    13. Electrical properties of materials. L1, P1    14. Optical properties of materials. L1, P1    15. Magnetic properties of materials. L1, P1    16. Test. P2   L – lecture, P – practiacal work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students must individually solve homework problems on the subjects of the lecture course. Homework solutions must be submitted in the specified time limits.  Students' individually studies literature related to the study course topics and prepares for seminar classes. | |
| ***Requirements for Awarding Credits*** | |
| Final mark consists of:  Intermediate tests:  1. Home works – 45%;  2. Tests (2) – 15%;  In order to be allowed to enter the exam, students must submit their homework. The mark in two written tests must be higher than "5".  Final examination:  3. Exam (combined; in 4 parts) – 40%  In Exam student solves one or several exercises and explains theory.  Lecture attendance - mandatory | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | | 1. Home works | x | x | x |  | x | x | x | x |  | x | x | x |  | | 2. Tests |  |  |  | x |  |  |  |  | x |  |  |  | x | | 3. Exam | x | x | x | x | x | x | x | x | x | x | x | x | x | | |
| ***Compulsory Reading List*** | |
| 1. Arfken, G., Weber, H., Harris, F. "Mathematical Methods for Physicists" 2. Askeland, D.R., Fulay, P. P., "Essentials of Materials Science and Engineering", 2nd edition, Cengage Learning, 2009. 3. Auzinsh, M., Budker D., Rochester S. Optically Polarized Atoms: Understanding light-atom interactions, 400 pages, Oxford University Press; 1 edition (September 10, 2010) 4. Callister, W. D. , Rethwisch, D. G., "Materials Science and Engineering: An Introduction", 8th edition, John Wiley & Sons, Inc., 2010 5. Irgens, F. “Continuum Mechanics” Springer 2008, ISBN: 978-3-540-74297-5 6. Riley, K., Hobson, M., Bence, S. "Mathematical Methods for Physics and Engineering" 7. Šarakovskis, A., Materiāli kursam Materiālu fizika un pielietojumi, Moodle vide. | |
| ***Further Reading List*** | |
| 1. Aleksandrov, E.B., M.P. Chaika, and G.I. Khvostenko, Interference of atomic states. Springer series on atoms + plasmas. 1993, Berlin ; New York: Springer-Verlag. ix, 250 p. 2. Auzinsh, M. and R. Ferber, Optical polarization of molecules. Cambridge monographs on atomic, molecular, and chemical physics. 1995, Cambridge ; New York: Cambridge University Press. xv, 306 p. 3. Budker, D., D.F. Kimball, and D.P. DeMille, Atomic physics : an exploration through problems and solutions. 2004, Oxford ; New York: Oxford University Press. xiv, 441 p. 4. Cahill, K., "Physical Mathematics" 5. Corney, A., Atomic and laser spectroscopy. 1977, Oxford ; New York: Clarendon Press. xvii, 763 p. 6. Edmonds, A.R., Angular momentum in quantum mechanics. 3d print., with corrections. ed. Investigations in physics. 1974, Princeton, N.J.: Princeton University Press. viii, 146 p. 7. Huard, S., Polarization of light. 1997, Chichester ; New York, Paris, Hohn Wiley, Masson xii, 333 p. 8. Nolting, W., "Theoretical Physics 1: Classical Mechanics" 9. Oliver, X., Agelet de Saracibar, C. “Continuum Mechanics for Engineers. Theory and Problems” Second Ed., doi:10.13140/RG.2.2.25821.20961 10. Reddy, J. N., “Principles of Continuum Mechanics: Conservation and Balance Laws with Applications“, Cambridge University Press, ISBN-13: 978-1107199200 11. Susskind, L. Hrabovsky, G., "The theoretical minimum: what you need to know to start doing physics" 12. Varshalovich, D.A., A.N. Moskalev, and V.K. Khersonski\*i, Quantum theory of angular momentum : irreducible tensors, spherical harmonics, vector coupling coefficients, 3nj symbols. 1988, Singapore ; Teaneck, NJ, USA: World Scientific Pub. x, 514 p. 13. Zare, R.N., Angular momentum : understanding spatial aspects in chemistry and physics. 2007, Mineola, N.Y.: Dover Publications, Inc. | |
| ***Periodicals and other sources*** | |
| 1. Free distribution service and an open-access archive, Mathematical Physics: <https://arxiv.org/archive/math-ph> 2. Žurnāls Physical Review A; 3. Žurnāls Physical Review Letters; 4. Žurnāls Reviews of Modern Physics; 5. Žurnāls Nature; 6. Žurnāls Science. | |
| ***Course Content*** |  |
| 1. **Elements of theoretical physics**    1. Non-dimensionalization. L4, P4       1. Identification of units;       2. Problem solving using analyses of dimensions (units);       3. Construction of solution from;       4. Identification of non-dimensionalization groups;       5. Solution construction using trivial cases;    2. General curve. L4, P4       1. Choice of physical scales (time, distance, etc.)       2. Identification of numerical parameters of the equation       3. Solving equations and obtaining a general curve       4. Identification of physical scales in experimental data       5. Obtaining a general curve from experimental data       6. Transformation of a physical situation into a differential equation    3. Fourier series. L2, P2       1. Projection of a periodic function in a Fourier series       2. Calculation of Fourier coefficient for periodic function;    4. Transformations. L6, P6       1. Propagation of a non-periodic function in a Fourier integral (Fourier transform)       2. Properties of the obtained function (Fourier image) and relation to the original function       3. Numerical calculation of Fourier transformation;       4. Identification of periodicity in data using Fourier transformation and other applications of Fourier transformation;       5. Laplace transformation;       6. Use of Fourier and Laplace transforms in solving differential equations (moving to image space) 2. **Mechanics of continuum media, introduction**    1. Introduction   Lecture 1   * + 1. The continuum hypothesis     2. Conservation laws     3. Euler/Lagrange approach     4. Differences between liquids and solids   1. Solid mechanics   Lecture 2   * + 1. Stress tensor – its obtainment and symmetries     2. Eigenstresses – the eigenvalue problem for the stress tensor     3. Stress tensor decomposition into deviatoric and volumetric parts. Invariants     4. Lecture 3     5. Deformation (strain) tensor     6. Full Hooke’s law between stress and strain tensors. Poisson’s coefficient, Young’s modulus and shear modulus, Lamé coefficients   Lecture 4   * + 1. Introduction in material strength – von Mises stress, Tresca criterion     2. Lecture 5 + 6 - practicals     3. Problem solving regarding matrix formulation in continuum mechanics     4. Obtainment, interpretation and visualization of results     5. Lecture 7     6. Euler-Bernoulli beam theory, differential equation for elastic beams     7. Lecture 8     8. Heat diffusion in a solid. Derivation of the heat equation     9. Lecture 9 + 10 – practicals     10. Problem solving regarding differential equations – problem construction, boundary conditions, obtainment of results   1. Hydrodynamics   Lecture 11   * + 1. Material derivative. Mass conservation, incompressibility     2. Navier-Stokes equation for an incompressible fluid   Lecture 12   * + 1. Standard simplifications of the Navier-Stokes equation – incompressible fluid, Stokes flow, inviscid fluid, fluid with no rotation   Lecture 13+14 – practicals   * + 1. Problems regarding simplification of the Navier-Stokes equation, full formulation of a physical problem in the context of hydrodynamics. Interpretation of results and analysis of their applicability bounds   Lecture 15   * + 1. Turbulence. Reynolds averaging (RANS) approach. Boussinesq hypothesis.     2. Diffusions equation in the RANS formalism   Lecture 16   * + 1. Introduction in computational fluid dynamics. Closure of equations with various models. Finite volume method (FVM) and finite element method (FEM).  1. **Atom - light interaction**   Students with prior knowledge in quantum physics at least at the level of the general physics course, but better after learning the course of the introductory quantum mechanics, will acquire intuitively easy-to-comprehend but, at the same time, a reasonably theoretical and precize introduction to the ideas of mechanisms and description of the interaction of atoms with light. Particular attention will be paid to account for the symmetry of the interaction which enables to make this description simpler and, in many cases, provide a practical description of the interaction of quantum mechanics almost exact, without using approximations which always decrease the exactness of the description. When developing a quantum mechanical description of atoms, the course provides an introduction to the description of atoms by means of a state density matrix. The course will highlight in particular the importance of the angular movement and its conservation requirements in the description of the interaction between atoms and light. After learning the course, students will be able to perform practical analysis of the light (especially laser radiation) interactions with atoms.  In particular, the course covers the following topics:   * 1. Atomic states;   2. Introduction to the quantum theory of the angular momentum;   3. Polarization of light;   4. Optical transitions in atoms. Selection rules;   5. Atoms in pure states;   6. Atoms in coherent states;  1. **Basics of materials physics**    1. Introduction to materials physics: What are materials. Historical aspects. Classification of materials. Creation and selection of materials    2. Atomic structure and interatomic bonds: Atomic structure. Electronic structure of atoms. Periodic table. Interatomic and intermolecular bonds. Formation of solids.    3. Structure of crystalline materials: Elements of crystallography: elemental cell, points, directions, planes. Short- and longrange order. Monocrystals, polycrystals, non-crystalline materials. Allotropic and polymorphic transformations. The most important material structures: NaCl, diamond, fluorite, perovskite, etc.    4. Defects in materials: Point defects: vacancies and interstitial atoms. Impurity defects. Linear defects - dislocations. Volume defects, grains, grain boundaries    5. Phase diagrams: Phases, microstructures, phase balance. Two-component phase diagrams: isomorphic and eutrophic alloys. Three-component phase diagrams. Iron-carbon phase diagrams, steels.    6. Metals and alloys: Ferrous and non-ferrous metals, metal alloys. Metal characteristic structures, density calculation. Heat treatment of metals, influence on mechanical properties. Metal processing and production    7. Ceramics and glasses: Silicate ceramics. Ceramics design and general properties. Silicate glasses, their structure. Glass ceramics    8. Test    9. Polymers: Formation of polymers. Polymer microstructure. Elastomers. General properties of polymers.    10. Composite materials: Fiber-reinforced composite materials. Particle reinforced composites. Laminate composite materials. "Sandwich" type panels.    11. Semiconductors: Independent and impurity semiconductors. Effects of temperature on the concentration and mobility of semiconductor charge carriers. Semiconductor devices.    12. Mechanical properties of materials: Strength and hardness. Young module. Deformation and collapse. Material fatigue.    13. Electrical properties of materials: Conductivity of materials. Electron and ion conductivity. Dielectrics. Piezoelectrics and ferroelectrics. Description of control within the framework of zone theory.    14. Optical properties of materials: Electromagnetic radiation. Light interaction with solids. Luminescence. Photoconductivity. Lasers. Optical fibers.    15. Magnetic properties of materials: Paramagnetics, diamagnetics, ferromagnets. Domains and hysteresis. Practical use of soft and hard magnets.    16. Test | |

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**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | **Academic practice of physic's master** |
|  | Physics and astronomy |
| ***Credits*** | 6 |
| ***Total Number of Contact Hours*** | 12 |
| ***Number of Lecture Hours*** | 0 |
| ***Number of Seminar and Practical Assignment Hours*** | 12 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 228 |
| ***Course Approval Date*** | 20.03.2021 |
| ***Course Developer*** | Dr.phys. Sandris Lācis, Dr. Paed. Lolita Jonāne |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the practice is to learn the professional skills and competences of the physicist in real professional activity, in an appropriate environment for traineeships.  Tasks of the practice are:   1. Familiarise yourself with the organisation of work in a traineeships workplace; 2. Train teamwork skills; 3. Apply knowledge and skill acquired during studies for solving modern physics problems in academic research, education or applied physics; 4. Train problem solving skills, communication skills, IT skills; 5. Develop competencies related to analytical thinking and physics research as well as ethical action.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** | |
| Knowledge:   1. Demonstrate basicknowledge of certain physical fields, according to the specialization of practice places: Atomic physics, nuclear physics and particle physics, condensed matter physics, materials physics, plasma physics, liquid and gas physics, mathematical and numerical methods in physics (MN2), astronomy (MN3); 2. Understands modern physics applications (MN4); 3. Demonstrates interdisciplinary knowledge (biophysics, medical physics, geophysics, etc. MN8), according to the specialization of the place of practice.   Skills:   1. Applies problem Solving Skills. (MV1); 2. Applies communication skills (MV4); 3. Applies IT skills (MV5); 4. Applies personal Skills (MV6);   Competence:   1. Applies analytical skills (MV2); 2. Applies research Skills (MV3); 3. Respects ethical behaviour in daily work (MV8). | |
| ***Course Plan*** | |
| 1. Introduction to the working area of the practice institution, tasks, and process of practice: week 1-5. S2 2. Fulfilment of the tasks set by the practice supervisor: week 6-12. S6 3. Preparation of the practice report: week 13-16. 4. Presentation of tasks performed during the practice. S4   S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Student independently:   1. gets acquainted with the written material that is needed to complete the tasks; 2. performs work according to the instructions of the practice supervisors; 3. prepares a report on the practice. | |
| ***Requirements for Awarding Credits*** | |
| At the end of the practice:   1. the student submits the following documents to the supervisor of the practice at the University:    1. Report on the success in reaching goals and tasks of the practice, according with the requirements of practice regulations. The report must be submitted on the form provided by the Physics department. It is signed by the practice supervisor at the host institution;    2. Letter of reference from the practice supervisor at the host institution. It contains information about the student's work during the practice, the quality of the student's work and the work discipline, as well as the marked assessment of the student's work. 2. The student presents his results of practice at a seminar with a brief presentation, answers to the expert’s questions and self-evaluates his / her growth. 3. Presentation is evaluated by the jury composed of at least three members drawn up from the commission for evaluating graduation papers.   Final examination:   1. Content and presentation quality of the Practice report - 20%; 2. The fulfilment of the traineeship tasks shall be based on a traineeship report, which shall be endorsed by the institution's practice leader - 30%; 3. Reference (description) for student work during the traineeship, given by Practice place supervisor - 20%; 4. The evaluation of the presentation at a seminar, answers to the expert questions and self-assessment the evaluation is given by the jury of at least three people, composed from the jury of the master's thesis -30%. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | | 1. Practice report (content, presentation) | + | + | + |  |  | + |  | + | + | + | | 2. Fulfillment of practice assignments (from report) | + | + | + | + |  |  | + | + | + |  | | 3. Reference of supervisor | + | + | + |  | + |  | + |  |  | + | | 4. Student's presentation in seminar | + | + | + | + | + | + |  | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. The UL Career Centre web-based information “Internship and work”:   <https://www.karjera.lu.lv/lv/studentiem-un-absolventiem/prakse-un-darbs/>   1. LU studējošo prakses organizēšanas noteikumi, apstiprināti ar LU 25.11.2019. rīkojumu Nr. 1/417 | |
| ***Further Reading List*** | |
| According to the supervisor instructions. | |
| ***Periodicals and other sources*** | |
| Websites of research institutions (for example, Institute of Solid State Physics of University of Latvia webside www.cfi.lu.lv’) | |
| ***Course Content*** |  |

1. Familiarity with the objectives and tasks of the practice and scope of the practice place. (S2)

The student familiarizes himself with the aim, tasks, requirements and recommendations of the practice, the by-law of practice and the samples of documents necessary for the practice process to be performed successfully.

2. Working on tasks assigned by the practice manager.

The student creates an individual plan and work schedule for the performance of practice tasks, coordinates it with the practice manager of the institution. The student familiarizes himself with the environment of practice, the equipment of rooms and safety requirements. The student performs tasks and experiences the application of physicist's professional skills in real professional activity. The student participates in the seminars organized by university practice manager and shares with the gained experience, receives consultative support.

3. Preparing a practice report.

The student compiles the work performed during the practice in report and hands it in to the university practice manager for assessment.

4. Presentation of tasks performed during the practice. (S4)

Students presents carried out work, perform a self-assessment, discuss the results and gives feedback from experts.

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**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Current topics in physics and astronomy I*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 18 |
| ***Number of Seminar and Practical Assignment Hours*** | 14 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.phys. Tija Sīle  Dr.phys. Guntars Kitenbergs |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| Aim of the study course is to stimulate student knowledge and understanding in newest scientific discoveries, while simultaneously developing their soft skills, particularly science communication skills.  Study course tasks are:  1. to master different scientific information research and communication types;  2. to get to know principles of modern physics education methods;  3. to learn about current research topics in the students field of interest in physics, astronomy and connected disciplines..  Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:  1. knows several actual topics in various disciplines of physics and astronomy (MN2, MN3), their use in interdisciplinary fields (MN8) and qualitatively understand the development of these topics (MN4);  2. manages terminology in English and Latvian about several current topics in physics and astronomy;  Skills:  3. finds, reads, analyzes and uses scientific literature (MV3, MV4);  4. presents and discusses scientific results in English and Latvian (MV4, MV7);  5. manages time, individual work and constructive collaboration with colleagues with various academic experience in order to reach study results (MV6);  6. prepares a part of a lecture or presentation, using ideas from modern physics education research (MN4, MV6);  Competence:  7. explains concepts and ideas of scientific literature in a structured way;  8. chooses and uses proper type of presentation to convey scientific information, depending on audience, contents and other factors. | |
| ***Course Plan*** | |
| 1. Introduction. Course structure, aim and motivation. Time planning. L2 2. Role of soft-skills in researcher career. L2 3. Popular science activities. L2 4. How to learn and teach. Actualities in Physics education research. L2 5. Abstracts and their preparation. L4 6. Literature review. L2 7. Presentations and their preparation. L4 8. Current topics in physics and astronomy. S14   L - lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work will involve preparation of various deliverables for assessments (described in section "Criteria for Evaluating Learning Outcomes"). In the beginning of the course students will be introduced to principles of preparing deliverables. Consultations (both remote and in person) will be available for unclear questions. | |
| ***Requirements for Awarding Credits*** | |
| Interim assessment:  1. Popular science project - 20%  2. Pedagogical work - 20%  3. Abstract - 20 %  4. Literature review - 20%  Final assessment:  5. Exam (presentation) - 20%  Students are let to the final examination only if all interim examinations are passed. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of Assessment | Learning Outcomes | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | | 1. Popular science work | x | x |  |  | x |  |  | x | | 1. Pedagogical work | x |  |  |  | x | x |  |  | | 1. Abstract | x | x | x |  | x |  | x | x | | 1. Review (Wikipedia page) | x | x | x |  | x |  | x | x | | 1. Exam (presentation) | x | x | x | x | x |  | x | x | | |
| ***Compulsory Reading List*** | |
| 1. Doumont, J., ed. English Communication for Scientists. Cambridge, MA: NPG Education, 2010 (https://www.nature.com/scitable/ebooks/english-communication-for-scientists-14053993) 2. Gabrys, B. J., Langdale, J.A. How to succeed as a scientist : from postdoc to professor. Cambridge University Press, 2012 (e-book) 3. Knight, R., Randall D. “Five easy lessons ;strategies for successful physics teaching”, ISBN 0805387021 | |
| ***Further Reading List*** | |
| 1. Bobroff, J. “Reimagining physics” Nature Nanotechnology 12, 496 (2017) 2. Bobroff, J., “Popularize Science. Why? How?“, Rīgā, 26.10.2018. https://www.facebook.com/zinatkongress/videos/201936060706749/ 3. Mazur, E. "Peer instruction : a user's manual" Prentice Hall, 1997 4. Pain, E. “How to (seriously) read a scientific paper”, Science https://www.sciencemag.org/careers/2016/03/how-seriously-read-scientific-paper 5. Physics Reimagined group webpage - <http://hebergement.u-psud.fr/supraconductivite/?lang=en> 6. Taylor, L., A. “Twenty things I wish I’d known when I started my PhD”, Nature Carrer Column <https://www.nature.com/articles/d41586-018-07332-x> | |
| ***Periodicals and other sources*** | |
| 1. E-print repository - arXiv.org 2. Google Scholar - https://scholar.google.com/ 3. Physical Review journals - <https://journals.aps.org/> 4. SCOPUS - https://www.scopus.com/ 5. Web of Science – https://www.webofknowledge.com/ | |
| ***Course Content*** |  |
| 1. Introduction. Course structure, aim and motivation. Time planning.  Introduction to the course and its structure. Discussion on the aim and motivation of the course. Examples of soft-skills applications. Time planning. Methods for improving time planning - to-do lists, Eisenhower method, frameseting. Gantt chart, deliverables, milestones.  2. Role of soft-skills in researcher career.  Various examples of use of soft-skills for a successful research career.  3. Popular science activities.  Activities for dissemination to general public other outreach, meaning, examples. Assessment of the achievement of activity. Practical exercise.  4. How to learn and teach. Actualities in Physics education research.  Introduction to modern teaching methods in physics and technology sectors. Key elements for lesson planning. Research on the physics education. Results.  5. Abstracts and their preparation.  The importance of abstracts, the basic principles.  Practical tasks with examples of abstracts and preparation of abstracts.  6. Literature review.  Introduction to the types of scientific literature, its search and access. Scientific literature databases (Web of Science, SCOPUS, Google Scholar). Typical structure and efficient reading techniques, analysis and use of scientific articles in ones work (storage of references, systematization — Mendeley). Types of science metric (IF, SNIP, h-index), usage, relevance to the scientific environment. Copyright issue in scientific literature. Open access and open science concepts, examples and opportunities. Practical task with examples of a review of literature.  7. Presentations and their preparation.  Forms and types of presentation of scientific information, their suitability for the situation, time planning. Basic principles for creating. Practical tasks with slide examples, creating a slide, and doing an Elevator pitch  8. Current topics in physics and astronomy  Students select and visit seminars of interest in physics, astronomy and related fields. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | ***Numerical simulation of physical processes*** |
| ***Brunch of Science*** | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 9 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** | 39 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 20.03.2021 |
| ***Course Developer*** | Dr.phys. Sandris Lācis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the study course is to provide physics master's education with an appropriate understanding of multifunctional modeling possibilities and their role in modern physics.  Tasks of the study course are:  1. To train the typical steps of multiphysical modeling;  2. To get acquainted with the peculiarities of modeling in different areas of physical processes;  3. To apply the theoretical skills acquired in previous studies in modeling of real physical processes;  4. To develop competence to analyze results, verify them and implement a feedback in order to improve the modeling approach;  5. To develop competence in formulating recommendations for optimizing physical processes;  6. To train presentation of research results skills and communication skills.  Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains elementary physical models on which equations describing continuous environmental physics are based (MN2.7, MN5, MN7.1); 2. Explains the boundary conditions used for specific physical quantities ​​(MN5, MN7.1, MV1);   Skills:   1. Creates computational geometry for COMSOL software (MN2.7, MV5); 2. Creates mesh for specified geometry (MN2.7, MV5); 3. Makes COMSOL calculations by adapting the grid as unnecessary (MN2.7, MV5); 4. Visualizes and analyzes COMSOL results (MN2.7, MV5); 5. Presents the results to classmates and to the lecturer (MV1);   Competence:   1. Selects a physical model suitable for the description of physical process, including task geometry and boundary conditions (MN5, MN7.1, MV1, MV6); 2. Explains the physical processes using the results of COMSOL modeling (MN7.3, MV6); 3. Develops recommendations for optimization of physical process using analysis of modelling results. (MN7.3, MV6). 4. Follows the basic ethical principles (MV8). | |
| ***Course Plan*** | |
| 1. Introduction. Calculations on heat conductivity for given meshes. L1 Ld3 2. Basic modeling phases. Geometry and mesh creation. Use of boundary conditions. Analysis of results. Scalar and vector fields. Integral parameters. Ld4 3. Heat transfer problem. L1 Ld3 4. Electric field. L1 Ld3 5. Magnetism. L1 Ld3 6. Seminar, presentation and mutual discussion of student solutions. S4 7. Solid state mechanics. L1 Ld3 8. Fluid mechanics. L1 Ld3 9. Seminar, presentation and mutual discussion of student solutions. S4 10. Mixed problem No 1. L1 Ld3 11. Mixed problem No 2. L1 Ld3 12. Mixed problem No 3. L1 Ld3 13. Seminar, presentation and mutual discussion of student solutions. S4 14. Individual problem of student. Ld4 15. Individual problem of student. Ld4 16. Seminar, mutual discussion of solutions for students' individual problems. S4   L - lecture, S – seminar, Ld - laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Student independently:  1. completes the lesson calculations and create laboratory work report,  2. carries out the calculation of the seminar tasks and prepares the seminar presentation,  3. completes an individual task, analyzes the results and prepare a presentation. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. 9 laboratory works - 45% 2. Presentation of results and activity during discussion in seminars - 20%   Final assessment:   1. Exam - Individual problem, completed and presented during the session - 35% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Pārbaudījumu veidi | Studiju rezultāti | | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | | 1. Completed laboratory works (9) |  |  | + | + | + | + |  | + |  |  | + | | 1. Presentation of results and activity during discussion in seminar | + | + |  |  |  | + | + |  | + | + |  | | 1. Exam |  | + | + | + | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Comsol: Learning center: https://www.comsol.com/learning-center 2. Comsol: Technical papers and presentations: https://www.comsol.com/papers-presentations | |
| ***Further Reading List*** | |
| 1. COMSOL5 for Engineers, Mehrzad Tabatabaian. 2. Multiphysics Modeling Using COMSOL 5 and MATLAB, Roger W. Pryor. | |
| ***Periodicals and other sources*** | |
| 1. Comsol: Application exchange <https://www.comsol.com/community/exchange/> 2. Comsol: Forum: https://www.comsol.com/forum | |
| ***Course Content*** |  |
| 1. Introduction to the finite element method: interpolation within elements and approximation of the solution in the calculation area. Calculations on heat management for finished grids. [L1, Ld3]  2. Basic stages of modelling. Creation of geometry and mesh. Application of boundary conditions. Analysis of results: visualization of scalar and vector fields, calculation of integral parameters. [Ld4]  3. Heat conduction problem. Heat fluxes in layered materials (effects of defects, eg "thermal bridges"). Heating at boundaries, heat distribution in two different materials (1D). Comparison with analytics. [L1 Ld3]  4. Electric field. Field generated by electrode configurations (radiation detectors). Evaluation of electrical conductivity in materials. Coil impedance: empty coil, aluminium and iron cores. [L1 Ld3]  5. Magnetism. The field created by two permanent magnets and the force of their interaction (3D, using symmetries). Comparison with analytics. Permanent magnet and iron wall modelling: nonlinear magnetization curve. [L1 Ld3]  6. Seminar, presentation of student solutions and mutual discussion [S4]  7. Mechanics of solids. Stress calculation for loaded wrench, safety criterion fulfillment test (3D). Calculation of internal forces in virtual sections. Visualization and analysis of real deformations. [L1 Ld3]  8. Fluid mechanics. Poisson flow in a cylindrical tube, comparison with analytics. Flow in a tube with a spherical barrier (2D using axial symmetry). Force calculation, contribution of pressure and viscous stresses. [L1 Ld3]  9. Seminar, presentation of student solutions and mutual discussion [S4]  10. Coupled problem. Flow in a rectangular cavern with different temperatures on the walls. Numerical features (application of point pressure limit condition). Natural convection in a square cavern (2D). [L1 Ld3]  11. Coupled problem. Thermal voltages caused by electric current and their relaxation after power off (2D using axial symmetry). [L1 Ld3]  12. Coupled problem. Inductive heating of a metal sample in the field of a coil (taking into account heat conduction and thermal radiation), material melting (2D using axial symmetry). [L1 Ld3]  13. Seminar, presentation of student solutions and mutual discussion [S4]  14. Coupled problems. Mixed problems of students' choice, problem formulation agreed with the lecturer. [Ld4]  15. Coupled problems. Mixed problems of students' choice, problem formulation agreed with the lecturer. [Ld4]  16. Seminar, presentation of students' solutions to individual problems and mutual discussion [S4] | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | ***Master thesis in physics I and II*** |
| ***Brunch of Science*** | Physics and astronomy |
| ***Credits*** | 20 |
| ***Total Number of Contact Hours*** | 0 |
| ***Number of Lecture Hours*** | 0 |
| ***Number of Seminar and Practical Assignment Hours*** | 0 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 800 |
| ***Course Approval Date*** | 22.04.2021 |
| ***Course Developer*** | Dr.phys. Sandris Lācis |
| ***Prerequisite Knowledge*** | Fizi5140 Fizikas maģistra specializācijas  FiziR009 Fizikas maģistra akadēmiskā prakse  Fizi5132 Aktualitātes fizikā un astronomijā I  Fizi5134 Pētnieciski laboratorijas darbi I  Fizi5137 Fizikālu procesu skaitliskā modelēšana |
| ***Study Course Abstract*** |  |
| The aim of the course is to ensure independent research in the chosen sub-area of physics under the supervision of the supervisor. This course ends with the defense of a master's thesis.  Tasks of the course are:  1. To develop students' skills and competence necessary for independent research work, including those related to the planning of scientific work;  2. To develop students' ability to analyse the results of their own research and that of others;  3. To improve students' communication skills by presenting the results of their research.  Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:  1. Demonstrates basic knowledge of certain fields of physics;  2. Explains the application of previously acquired knowledge in interdisciplinary fields;  Skills:  3. Uses mathematical apparatus for formulation, solution of physical problems and analysis of observed processes;  4. Plans and performs experiments or calculations, selects and applies analysis methods suitable for the obtained data, evaluates errors of result;  5. Uses developed communication skills;  Competence:  6. Demonstrates qualitative of current developments at the frontiers of the physics discipline;  7. Compares the obtained results with theoretical models;  8. Trains research competence in independent research, searches information in scientific literature, gathers information, communicates with colleagues;  9. Uses ethical behavior competence in research. | |
| ***Course Plan*** | |
| *Not necessary for master thesis and other graduation papers. (LU Studiju kursu izstrādes un aktualizācijas kārtības 1. Pielikums)* | |
| ***Characterization of students' independent work organization and tasks*** | |
| Individual research work, preparation of a master thesis template. | |
| ***Requirements for Awarding Credits*** | |
| Final grade consists of:  Intermediate test:  1. Presentation of the Master's thesis concepts - 50%  The concept of the Master’s thesis include the theoretical part with a literature review. The theoretical part is submitted separately, at least 3 working days before the presentation the Master's thesis concept. Study course has been "failed" if the concept has significant deficiencies. The study course is assessed with a pass or fail.  Final examination:  2. Defense of a master’s thesis – 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | | 1. Concept of master’s thesis | x | x | x | x | x | x | x | x | x | | 1. Defense of a master’s thesis | x | x | x | x | x | x | x | x | x | | |
| ***Compulsory Reading List*** | |
| 1. Latest scientific literature in physics and relevant subtopics.  2. Monographs in the relevant subtopics. | |
| ***Further Reading List*** | |
| 1. Daintith, J. A Dictionary of Physics (Oxford Paperback Reference), Oxford University Press, USA; 5 edition, 2005, 592 pages 2. Prasības noslēguma darbu (bakalaura, maģistra darbu, diplomdarbu un kvalifikācijas darbu) izstrādāšanai un aizstāvēšanai Latvijas Universitātē, (LU 03.02.2012. rīkojums Nr.1/38) 3. Zelgalvis, E., Bakalaura, maģistra darbu, diplomdarbu un kursa darbu izstrādāšanas un aizstāvēšanas metodiskie norādījumi. Rīga: LU, 1999. 1 eks. | |
| ***Periodicals and other sources*** | |
| 1. ISI Web of Knowledge: http://www.webofknowledge.com 2. LU Bibliotēkas tīmekļa vietne: http://www.biblioteka.lu.lv/e-resursi/ 3. Physical Review Online Archive: https://journals.aps.org/archive/ 4. Science Direct: <http://www.sciencedirect.com/> | |
| ***Course Content*** |  |
| *Not necessary for master thesis and other graduation papers. (LU Studiju kursu izstrādes un aktualizācijas kārtības 1. pielikums)* | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Basic Latvian*** |
|  | *Linguistics* |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** |  |
| ***Number of Seminar and Practical Assignment Hours*** | 32 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 31.05.2019 |
| ***Course Developer*** | Dr.paed. Inta Līsmane |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The objectives of the course - to build the communicative and intercultural competence for the further application of the knowledge of Latvian in the study process and professional activities.  The course has been developed in accordance with the A1 level requirements of the content specifications set by the European Council.  The course syllabus has been designed to help the learners function in elementary social situations, promote the acquisition of new lexis and grammar necessary for everyday communication, and form a firm basis for further communication in the target language.  Tasks of the course are:   1. to give knowledge about the vocabulary, phonology and syntax of the Latvian language in order to develop linguistic competence; 2. to acquire the basics in the perception of the Latvian language, gradually developing reading, writing, listening and speaking skills; 3. the development of the communication skills is based on the grammar paradigms of the Latvian language.   The language of instruction is Latvian. | |
| ***Learning Outcomes*** |  |
| Knowledge:  1. Understands the system and practical functions of the Latvian language;  2. Manages basic vocabulary of individual words and phrases relevant to specific situations;  Skills:  3. Performs receptive reading and listening tasks (level A1);  4. Understands very slow and correctly articulated speech, elementary phrases and simple sentences (level A1);  5. Performs productive tasks of speaking and writing, is able to pronounce words, express statements and denials, is able to write words and phrases (level A1):  6. Provides and obtains information, communicates in specific everyday situations, asks and provides answers to basic questions orally and in writing (level A1):  Competence:  7. Carries out communicative competence of the language by performing communication tasks and interacting with communication partners;  8. Accepts communication norms in a new cultural environment, does not use statements that may cause misunderstandings or offend the participant in communication, demonstrates openness, empathy and intercultural competence. | |
| ***Course Plan*** | |
| 1. Personal identity. P8 2. City or the countryside. P8 3. Student life. P8 4. Education and social environment. P8   P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Student work is organized individually and/or in smaller groups:   1. To acquire the necessary thematic vocabulary; 2. Prepare for lexical and grammar tests. 3. Use available internet resources for language learning. 4. Prepare 4 dialogues and 1 presentation. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. 2 lexical and grammatical tests – 50%. 2. Oral tasks and tests – 25%.   Final assessment:   1. Examination (written and oral) – 25%. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | | 1. Midterm test (written) | X | X | X |  |  | X |  |  | | 1. Midterm test (written) | X | X | X |  |  | X |  |  | | 1. Midterm test (oral) | X | X |  | X | X |  | X | X | | 1. Exam (oral and written) | X | X |  | X | X |  | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Auziņa, I. (u.c.) Laipa A1. Rīga: LVA, 2014, 184 lpp. 2. Katrai nodarbībai tiek sagatavoti mācību materiāli (gramatikas skaidrojums, jaunās leksikas vārdnīca). | |
| ***Further Reading List*** | |
| 1. Auziņa, I., Nešpore, G. (2014). Latviešu valodas darbības vārdu tabulas. Rīga: LVA. 2. Šalme, A., Ūdris, P. (1996; atkārtots izdevums 2004). Do it in Latvian! Latviešu valodas sākumi pašmācībai angliski runājošajiem. Rīga: Apgāds ”SI”. | |
| ***Periodicals and other sources*** | |
| 1. Māci un mācies latviešu valodu. Audiomateriāli. (LVA http://maciunmacies.valoda.lv/valodas-apguve/e-materiali/uzdevumi). 2. Māci un mācies latviešu valodu. Lasīšanas teksti. (LVA http://maciunmacies.valoda.lv/valodas-apguve/e-materiali/lasisanas-teksti). 3. Valodu portfelis pieaugušajiem. Pašnovērtējums. (LVA http://maciunmacies.valoda.lv/images/speles/Language-Portfolio/default.html). 4. Interaktīva vārdnīca krievu, angļu, franču, vācu valodā. (LVA http://www.sazinastilts.lv/language-learning/vocabulary/). | |
| ***Course Content*** |  |
| **1. Personal identity – P (8)**  1.1. The Latvian alphabet, pronunciation and stress: personal names.  1.2. Professions and occupation.  1.3. Grammar: irregular verb “to be”; pronouns, numbers; demonstrative pronouns, nouns (nominative – who? what?).  1.4. Conversation theme: get acquainted with students by greeting and introduce myself.  1.5. Countries and capitals.  1.6. Languages un nationalities.  1.7. Grammar: verbs; preposition – from, nouns (locative - where?); adverbs.  1.8. Conversation theme: to exchange personal information (to say which languages you speak and where you are from, to talk about nationality).  **2. City or the countryside – P (8)**  2.1. My city. My flat in Riga.  2.2. This is my family. Family house in the countryside.  2.3. Grammar: verbs; adjective; prepositions with accusative; numbers; pronouns.  2.4. Conversation theme: streets on the map, asking for direction.  2.5. (1st) test on vocabulary and grammar.  **3. Student life – P (8)**  3.1. My week: daily life and weekend.  3.2. My meals: breakfast, lunch and dinner.  3.3. My shopping: food, clothing and footwear.  3.4. Grammar: time; numbers and ordinal numbers; nouns (genitive: whose?); prepositions with genitive; verbs.  3.5. Conversation theme: at what time? Expressing necessity and to talk about likes and dislikes.  3.6. (2nd) test on vocabulary and grammar.  **4. Education and social environment – P (8)**  4.1. My studies: 1st year, 1st semester, my group, my interests, my future plans.  4.2. Leisure, vacation and holidays.  4.3. Hobbies, friends and acquaintances.  4.4. Sports & Health.  4.5. Grammar: nouns (reading); verbs; nouns (dative question – to/for whom/what?); prepositions with dative.  4.6. Communication: information for education, work experience, for free time, hobbies and sport. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | ***Nanotechnologies and Nanomaterials*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 28 |
| ***Number of Seminar and Practical Assignment Hours*** | 4 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 04.03.2021 |
| ***Course Developer*** | Dr.phys. Aivars Vembris |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to provide a review about nanomaterials and to explain the differences of physical properties between nano and macroscopic objects. The methods of development of nanostructures and nano-devices as well as the experimental characterization of nanomaterials will be discussed. In conclusion will be given information about nanomaterial toxicity problems.  Tasks of the course are:   1. To learn about nanomaterials and their production technologies; 2. To identify possibilities of using nanomaterials and nanotechnologies; 3. To understand the risks associated with the use of nanomaterials in daily products.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands the laws of physics for nanomaterials; 2. Identifies the main applications of nanoscience;   Skills:   1. Independently reads the literature and presents results at seminārs; 2. Studies and conducts research in the field of nanoscience;   Competence:   1. Independently chooses nanostructures fabrication and research methods; 2. Identifies nanomaterial toxicity problems. | |
| ***Course Plan*** | |
| 1. Introduction to nanomaterials and nanotechnologies L2 2. Technology for investigation of nanomaterials L2 3. Nanomaterials L4 4. Properties of nanomaterials L4 5. Preparation of nanomaterials and their structures L4 6. Applications of nanomaterials L4 7. Metamaterials L2 8. Molecular electronics L4 9. Nanomaterial toxicity L2 10. Hot topics in nanoscience S4   L – lecture, S – seminar, P - practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| It is necessary to get acquainted with the latest trends in the field of nanomaterials and nanotechnologies. To be read in the available scientific literature. | |
| ***Requirements for Awarding Credits*** | |
| In order to pass the course students must prepare a presentation and in the end of the course students have to pass the final exam.  Intermediate test:   1. Presentation - 50%   Final exam:   1. Exam (oral) - 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Presentation | + | + | + | + | + | + | | 1. Exam | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Ashby,A., Ferreira, P., Schodek, D. Nanomaterials and nanotechnologies and design. Butterworth-Heinemann, 2009, 560 lpp. 2. Cuevas, J.C., Scheer, E. Molecular Electronics An Introduction to Theory and Experiment. World Scientific Publishing Co. Pte. Ltd. 2010, 703 lpp 3. Di Ventra, M., Evoy,S., Heflin, J.R. Introduction to nanoscale science and technology, Jr. New York : Springer, 2004. xiii, 611 lpp. 4. Kelsall, R.W., Hamley, I.W., Geoghegan, M. Nanoscale science and technology. Chichester, England ; Hoboken, NJ : John Wiley, c2005. xv, 456 lpp. 5. Mirkin, C.A., Niemeyer, C.M. Nanobiotechnology. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2004, 469 lpp. 6. Monteiro-Riviere, N.A., Lang, C. Tran NanotoxicologyP rogress toward Nanomedicine. CRC PressTaylor & Francis Group. 2016. 514 lpp. | |
| ***Further Reading List*** | |
| 1. Bâldea, I. Molecular Electronics An Experimental and Theoretical Approach. CRC Press Taylor & Francis Group, 2015, 448 lpp. 2. Datta, S., 1954-: Electronic transport in mesoscopic systems /Supriyo Datta. Cambridge [etc.] : Cambridge University Press, 1995. xv, 377 lpp 3. Martínez-Duart, J. M.: Nanotechnology for microelectronics and optoelectronics /J.M. Martínez-Duart, R.J. Martín-Palma, F. Agulló-Rueda. Amsterdam : Elsevier, c2006. xix, 279 lpp 4. Mirkin, C.A., Niemeyer, C.M. Nanobiotechnology II. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2007, 432 lpp. 5. Schliwa, M. Molecular Motors. WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim. 2003. 582 lpp. 6. Waser, R. Nanoelectronics and information technology :advanced electronic materials and novel devices. Weinheim : Wiley-VCH, c2005. 995 lpp. | |
| ***Periodicals and other sources*** | |
| 1. Nano Hub: www.nanohub.org | |
| ***Course Content*** |  |
| Theme 1. Introduction to nanomaterials and nanotechnologies  Lecture 1. Introduction to nanomaterials and nanotechnologies  Object scale. Definition of nanomaterials and nanotechnologies. Overview of nanomaterials. Comparison with the macroscopic world. Technologies for the development and research of nanomaterials. History.  Theme 2. Technologies for nanomaterials research  Lecture 2. Microscopy  Principles of microscopy. Transmission electron microscope, scanning tunneling microscope, atomic force microscope and other scanning microscopes. Operating principles.  Theme 3. Nanomaterials  Lecture 3. Classification of nanomaterials  0D, 1D, 2D, 3D materials and their structures. Measure effect and their effect on physical properties.  Lecture 4 Carbon nanomaterials  Carbon allotropes. Orbital hybridization. Fullerenes. C60, carbon nanotubes, graphene. Their properties, production methods and applications.  Theme 4. Properties of nanomaterials  Lecture 5. Physical properties of nanomaterials  Mechanical properties. Thermal properties. Electrical properties.  Lecture 6 Physical properties of nanomaterials II  Magnetic properties. Optical properties. Acoustic properties.  Theme 5. Development of nanomaterials and structures  Lecture 7. Synthesis of nanomaterials  Overview of methods for obtaining nanomaterials. Inert gas expansion, Molecular self-assembly, Electrodeposition, Physical vapor deposition, chemical vapor deposition. VLS nanowire growth, Stranski-Kostanova growth regime, fullerenes and carbon nanotubes.  Lecture 8. Self-organization  Functional organic molecules. DNA self-organization. Hierarchical, directed and algorithmic self-organization. DPN lithography. Epitaxial method.  Theme 6. Applications of nanomaterials  Lecture 9. Applications of nanomaterials  MEMS and NEMS devices. Electromechanical relays, low mass and high acceleration sensors. Surface coatings. Light emitters. Energy production. Costs of nanomaterials.  Lecture 10. Biological applications of nanomaterials  Biological nanomotors and nanoevices. Myosin and kinesin motors. (myosin, and microtubules motors) Laboratory on chip.  Theme 7. Metamaterials  Lecture 11. Hair materials  Magnetic and dielectric permeability for semiconductors, dielectrics and metals. Negative dielectric and magnetic permeability. Materials and structures of negative refractive index.  Theme 8. Molecular electronics  Lecture 12. Basics of molecular electronics  Molecular electronics and its history. Substances for molecular electronics. Contact connection technique.  Lecture 13. Molecular electronics theory  Distribution of electrons in one molecule. Conductivity processes in one molecule and at contact sites. Thermal and phonon effects.  Theme 9. Toxicity of nanomaterials  Lecture 14. Toxicity of nanomaterials  Impact of nanomaterials on wildlife. Risk assessment. Hazards and risk characterization related to health and genetic effects. Possible toxicity tests.  Theme 10. The most relevant in nanoscience  Seminar, where students present their own reports on the latest research in nanoscience. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Introduction to Solid state physics*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 28 |
| ***Number of Seminar and Practical Assignment Hours*** | 4 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 17.03.2021 |
| ***Course Developer*** | Dr.habil.phys. Uldis Rogulis  Dr.phys. Jurģis Grūbe |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to provide advanced knowledge about the structure of solids, nature of their energetic bands, as well as provide a systematic review about the phenomena and properties of solids in various external fields.  Tasks of the course are:   1. introduce at the advanced level the principles of the creation of the solid state structures as well as the properties which follow from the periodical lattice of atoms as well as peculiarities of the amorphous solids; 2. introduce a systematic knowledge about the regularities in the periodical atomic-electronic systems, which determine their mechanical, thermic, optical, electrical, dielectric and magnetic properties.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Describes the structure of solids and their properties; 2. Explains condensed matter physics; 3. Describes materials physics;   Skills:   1. Chooses the necessary experimental equipment for the characterization of solids properties; 2. Uses theoretical models to describe the properties of solids;   Competence:   1. Acquires specific sub-fields of the solid state physics, and engages in the theoretical and practical research work in solid state physics and material sciences. | |
| ***Course Plan*** | |
| 1. Crystal structure and symmetry elements. L2 2. Reciprocal lattice and diffraction in crystals. L2 3. Lattice vibration, phonons. L2 4. Free electrons in metals. L2 5. Band theory - weakly bounded electron approximation. L2 6. Band theory – tightly bounded electron approximation. L2 7. Energy levels and charge carrier statistics in semiconductors. L2 8. Phenomena in semiconductors, p-n junction. L2 9. Test. P2 10. Dielectrics, ferroelectrics. L2 11. Optical properties of solids. L2 12. Magnetic properties: diamagnetism, paramagnetism, ferromagnetism. L2 13. Superconductivity. L2 14. Defects in solids. L2 15. Amorphous solids. L2 16. Test. P2   P – practical work, L – lecture | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work takes place individually and / or in small work groups.  Independent tasks are to:   1. study the literature related to the course topics; 2. using the course Moodle materials, prepare for tests; 3. prepare for the course exam. | |
| ***Requirements for Awarding Credits*** | |
| During the semester, 2 tests are planned.  The final mark consists of:  Intermediete tests:   1. Tests Nr.1 - 25% 2. Tests Nr.2 - 25%   Final exam:   1. Exam (oral) - 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Types of tests | Study results | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | | 1. Test Nr.1 | + | + | + | + | + | + | | 1. Test Nr.2 | + | + | + | + | + | + | | 1. Exam | + | + | + |  |  | + | | |
| ***Compulsory Reading List*** | |
| 1. Ashcroft, N. W., Mermin, N. D. Solid state Physics, Holt, Rinehart&Winston, 1976 2. Blakemore, J. S. Solid state Physics, Cambridge Univ. Press, 1985 3. Kittel, Ch. Introduction to Solid State Physics, 8th Edition, Wiley&Sons, NY, 2005. 4. Rosenberg, H. M. The Solid State, 1978 5. Павлов, П. В., Хохлов, А. Ф., Физика твердого тела, M, Высшaя школа, 1985. | |
| ***Further Reading List*** | |
| 1. Lou, L. Introduction to Phonons and Electrons, 2003 2. Marder, M. P., Condensed Matter Physics, 2010 3. Šaļimova, K. Pusvadītāju fizika, Rīga, Zvaigzne, 1973 4. Siliņš, A.,Truhins, A. "Point Defects and Elementary Excitations in Crystalline and Glassy SiO2", Rīga, Zinātne, 1985 (krievu val.) 5. Simon, S.H. The Oxford Solid State Basics, 2013 | |
| ***Periodicals and other sources*** | |
| 1. Stanford University [www.stanford.edu/group/fisher/teaching/Ph172/](http://www.stanford.edu/group/fisher/teaching/Ph172/) | |
| ***Course Content*** |  |
| **1. Lecture** (2 hours)**.** **Crystal structure and symmetry elements.**  14 Brave lattices, crystalline syngonies. Elements of two-dimensional symmetry. Elements of three-dimensional symmetry. Wigner-Seitz elementary cell. Crystallographic notations, Miller indices.  **2. Lecture** (2 hours)**. Reciprocal lattice and diffraction in crystals.**  Inverse lattice. X-ray, electron and neutron diffraction in the crystal, structure factor, atomic scattering factor.  **3. Lecture** (2 hours)**. Lattice vibration, phonons.**  Brillouin zones. Heat capacity of solids, classical, Einstein, Debye theories. Phonons, phonon frequency dispersion.  **4. Lecture** (2 hours). **Free electrons in metals.**  Free electron gas model. Fermi energy, Fermi surface. Fermi-Dirac distribution. Electrical conductivity in metals, Drude’s metal theory. Thermal conductivity in metals, Wiedemann–Franz’s law.  **5. Lecture** (2 hours). **Band theory - weakly bounded electron approximation.**  Schroedinger equation for solids. Adiabatic approximation. Weakly bounded electron approximation, Bloch’s functions, quasi-impulse.  **6. Lecture** (2 hours). **Band theory – tightly bounded electron approximation.**  Principles of band formation in solids. Approximation of tightly bounded electrons. Bands in metals, dielectrics and semiconductors.  **7. Lecture** (2 hours. **Energy levels and charge carrier statistics in semiconductors.**  Charge carriers in semiconductors - electrons and holes. Intrinsic and impurity semiconductors, n-type and p-type semiconductors. Semiconductor conductivity. Fermi - Dirac statistics, Fermi level.   1. **Lecture** (2 hours)**.** **Phenomena in semiconductors, p-n junction.** 2. Phenomena in semiconductors in electric and magnetic fields. p-n transition in semiconductors, diffusion and drift currents, semiconductor devices.   **9. Test work** (2 hours)**.**  **10. Lecture.** **Dielectrics, ferroelectrics** (2 hours)**.**  Polarization. Polarization mechanisms in dielectrics. Dielectrics in an external electric field. Dielectric constant. Flat-parallel capacitor. Internal fields. Dependence of dielectric properties on electric field frequency. Ferroelectrics, their properties. Piezoelectrics. Dielectric breakdown.  **11. Lecture.** **Optical properties of solids** (2 hours)**.**  Light absorption and emission. Direct and indirect optical transitions. Electro-optical properties: photoconductivity, photodiodes, laser diodes, photovoltaic cells. Quasi-particles in solids: excitons, plasmons, polarons, polaritons.  **12. Lecture.** **Magnetic properties: diamagnetism, paramagnetism, ferromagnetism** (2 hours)**.**  Magnetic properties of solids - diamagnetics, paramagnetics, ferromagnets. Magnetic structures in solids and their characteristics. Magnetic resonance in solids.  **13. Lecture.** **Superconductivity** (2 hours)**.**  Superconducting properties, cooper pairs. First and second types of superconductors. Tunneling effects in superconductors. High temperature superconductors.  **14. Lecture.** **Defects in solids** (2 hours)**.**  Point defects in solids. Schottky and Frankel defects. Colour centres. Dislocations. Defects in alloys.  **15. Lecture. Amorphous solids** (2 hours).  Classification and production of amorphous substances. Structural models. Defects and homogeneity. Diffraction effects in amorphous substances, distribution functions. Electrical conductivity. Band structure. Optical properties. Superconductivity. Specific heat capacity. Thermal conductivity. Magnetism.  **Test work** (2 hours)**.** | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Thin Film Science and Deposition Technologies*** | |
|  | Physics and astronomy | |
| ***Credits*** | 4 | |
| ***Total Number of Contact Hours*** | 64 | |
| ***Number of Lecture Hours*** | 50 | |
| ***Number of Seminar and Practical Assignment Hours*** | 0 | |
| ***Number of Laboratory Work Hours*** | 14 | |
| ***Independent Study Hours*** | 96 | |
| ***Course Approval Date*** | 17.03.2021 | |
| ***Course Developer*** | Dr.phys. Edgars Butanovs, Dr.Phys. Mārtiņš Zubkins | |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. | |
| ***Study Course Abstract*** |  | |
| The aim of the course is to give insight in thin films science and to provide practical skills in working with modern film deposition equipment.  Tasks of the course are to:   1. familiarize with thin films physics and deposition principles; 2. gain insight into various thin film deposition technologies; 3. gain insight into the applications of thin films; 4. gain experience and practical skills in working with modern film deposition equipment; 5. analyse and choose the optimal deposition method depending on the desired material and application.   Languages of instruction are Latvian and English. | | |
| ***Learning Outcomes*** |  | |
| Knowledge:   1. Understands of thin films physics, deposition principles and applications;   Skills:  2. Reads literature independently;  3. Evaluates and analyses physical and technical problems encountered in laboratory exercises;  Competence:  4. chooses and describes the optimal deposition method independently depending on the film material and desired application;  5. does practical experience in working with modern thin film deposition equipment. | | |
| ***Course Plan*** | | |
| 1. Thin film science and deposition techniques. L14 Ld2 2. Thermal, electron beam and ion beam deposition. L4 Ld2 3. Pulsed laser deposition (PLD). L2 4. Molecular beam epitaxy. L2 5. Plasma deposition technologies. L2 Ld2 6. Magnetron sputtering. L8 Ld4 7. Transparent conducting oxide (TCO) thin films deposition and applications in transparent electronics. L4 8. Electro-chromic and thermo-chromic thin films deposition and devices. L4 9. Chemical vapour deposition (CVD) and atomic layer deposition (ALD). L6 Ld2 10. Wet casting methods and spin-coating method. L4 Ld2   L – lecture, Ld – laboratory work | | |
| ***Characterization of students' independent work organization and tasks*** | | |
| 1. Students should familiarize themselves with lecture notes independently after each lecture; 2. Students should prepare for laboratory exercises by carefully studying the description and reading additional literature before the exercise; 3. Students must prepare and defend all laboratory exercise protocols before taking the exam; 4. Students should prepare themselves for the exam by reading the lecture notes, presentations, and the given literature. | | |
| ***Requirements for Awarding Credits*** | | |
| Intermediate tests:   1. Laboratory works (6) – 50%   Final exam:   1. written exam – 50% | | |
| ***Criteria for Evaluation Learning Outcomes*** |  | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | 1. | 2. | 3. | 4. | 5. | | 1. Laboratory works | X |  | X | X | X | | 1. Exam | X | X |  | X |  | | | |
| ***Compulsory Reading List*** | | |
| 1. Ohring, M. Materials Science of Thin Films, 2001 Academic Press ISBN: 0125249756. 2. Seshan, K. Handbook of Thin Film Deposition Processes and Techniques (Second Edition), 2001 William Andrew Inc. ISBN: 978-0-8155-1442-8. 3. Smith, D.L. Thin-Film Deposition: Principles and Practice 1st Edition, 1995 McGraw-Hill Professional Publishing, ISBN-13: 978-0070585027. 4. Smith, D.J., Granqvist, C.G. Green Nanotechnology - Solutions for Sustainability and Energy in the Built Environment, 2010 Taylor & Francis Inc. ISBN 978-1-4200-8532-7. | | |
| ***Further Reading List*** | | |
| 1. Jones, A.C., Hitchman, M.L. Chemical Vapour Deposition: Precursors, Processes and Applications, Royal Society of Chemistry, 2009, ISBN: 978-0-85404-465-8 2. Martin, P., M. (Ed.) Handbook of Deposition Technologies for Films and Coatings, Elsevier 2005, ISBN: 9780815520313 3. Michely, T., Krug, J. Islands, Mounds and Atoms, Springer, 2004, ISBN: 978-3-642-18672-1 | | |
| ***Periodicals and other sources*** | | |
| 1. Jones, A.C., Hitchman, M.L. Chemical Vapour Deposition: Precursors, Processes and Applications, Royal Society of Chemistry, 2009, ISBN: 978-0-85404-465-8 2. Martin, P., M. (Ed.) Handbook of Deposition Technologies for Films and Coatings, Elsevier 2005, ISBN: 9780815520313 3. Michely, T., Krug, J. Islands, Mounds and Atoms, Springer, 2004, ISBN: 978-3-642-18672-1 | | |
| ***Course Content*** |  | |
| 1. Thin films science and deposition techniques   Introduction to thin films science and deposition techniques. Basic concepts and methods. Physical, chemical, electrochemical and wet deposition. Physical and chemical processes. Special techniques and applications.  Surface processes.  Elementary thermodynamic ideas of surfaces. Thermodynamic potentials and the dividing surface. Surface tension and surface energy. Surface energy and surface stress. The terrace-ledge-kink model. Wulff construction and the forms of small crystals. Thin film growth. Thermodynamics versus kinetics. Thermodynamics of the vapor pressure. Adsorption and Nucleation. Kinetics of Thin Film Growth. Thin film morphology-zone structure model. Introduction to vacuum technologies. Kinetic theory concepts. Arrival rate of atoms at a surface. The molecular density.  The mean free path. The monolayer arrival time.  Vacuum system volumes, leak rates and pumping speeds. Production of low, high and ultrahigh vacuum. Measurement of pressure and gas flow in coating deposition systems. Low vacuum, HV and UHV hardware: pumps, tubes, materials and pressure measurement. Types of pumps. Chambers, tube and flange sizes. Choice of materials. Surface preparation and cleaning procedures: in-situ experiments. Sample transfer devices.  Laboratory exercise: Vacuum technology.   1. Thermal evaporation, electron and ion beam deposition.   Introduction to thermal evaporation, electron beam and ion beam deposition. Physical principles of thermal evaporation. Melting and sublimation, vapour pressure. Instrumentation: vacuum chambers, vacuum pumps, thermal evaporators, e-beam and i-beam guns, in-situ film thickness monitoring equipment. Advantages of thermal, e-beam and i-beam techniques. Application examples.  Laboratory exercise: Thermal evaporation.   1. Pulsed laser deposition   Pulsed laser deposition. Physics of laser ablation, plume composition and dynamics. Process parameters: laser parameters (power, pulse duration, frequency), gas pressure, substrate temperature. Instrumentation: pulsed lasers, vacuum chamber, targets, gases. Advantages and disadvantages of PLD. In situ monitoring tools of plasma composition and thin film growth; ex situ sample characterization. Examples of applications.   1. Molecular beam epitaxy   Molecular beam epitaxy. Evaporation and molecular ‘beams’. Surface preparation. Instrumentation: UHV vacuum chamber with load lock system, evaporators (Knudsen cell or e-beam) and gas sources, integrated film growth control, computer control. Area of applications and main advantages of MBE.  Popular MBE materials and application examples.   1. Plasma deposition technologies   Fundamentals of plasma. Plasma characterisation. Optical emission spectroscopy of plasma.  Laboratory exercise: Optical emission spectroscopy of plasma.   1. Magnetron sputtering   Processes driving magnetron sputtering:  plasma ion - solid target interaction, sputter yield, secondary electron emission, DC cathodic discharge, magnetron discharge. DC cathodic sputtering and magnetron sputtering. Discharge voltage behaviour and processes during cathodic and magnetron sputtering. Comparison DC and RF magnetron sputtering. Balanced and unbalanced magnetron sputtering. Plasma characterization and plasma diagnostics. Magnetron co-sputtering. Hardware. Applications.  Laboratory exercise: Magnetron DC and RF sputtering.  Reactive magnetron sputtering. Gas balance equations. Discharge voltage behaviour during reactive sputtering. Feedback control. Target poisoning. Process stability. Preferential sputtering. Negative ion emission. Industrial applications. Sputter deposition onto polymer flexible substrates in a roll-to-roll configuration.  High Power Impulse Magnetron Sputtering (HIPIMS). Discharge voltage behaviour during HIPIMS sputtering.  Plasma characterization and plasma diagnostics. Substrate biasing: etching / growth assist. Interface engineering by using HIPIMS plasmas. Deposition and coatings by HIPIMS. Hardware. Applications.  Laboratory exercise: Reactive magnetron sputtering and HIPIMS.   1. Transparent conductive oxide (TCO) thin film deposition and applications in transparent electronics   Magnetron sputtering of transparent conducting oxides and co-sputtering. AZO, ITO and other TCO: fundamentals, deposition, properties, and applications. Comparison of TCO thin films: Indium tin oxide (ITO), Aluminium doped ZnO (AZO). Amorphous TCO. Deposition by DC, RF and HIPIMS magnetron sputtering.   1. Electrochromic and thermochromic thin films and devices   Fundamentals, deposition, properties, and applications. Deposition of WO3 cathodic thin films and properties. Deposition NiO anodic thin films and properties.   1. Chemical Vapour Deposition (CVD) and Atomic Layer Deposition (ALD)   Chemical Vapour Deposition (CVD) and Atomic Layer Deposition (ALD) – Low Pressure CVD (LPCVD), Plasma Enhanced CVD (PECVD), Metal Organic CVD (MOCVD), ALD, Plasma Enhanced ALD (PEALD). Introduction and principles of chemical deposition processes. Thermodynamics and chemistry of thin film deposition.  Design of Chemical Deposition equipment – Vacuum systems, chambers, gas mixing systems, heaters, process management, environment and safety issues. Process control parameters and In-Situ monitoring tools. Substrates and precursor materials.  Industrial applications of chemically deposited thin films. Crystal growth for optics and substrates, Anti reflective coatings, dielectric mirrors and spectral filters. Light Emitting Diodes (LEDs) and other electronics devices.  Laboratory exercise: Introduction to semi-industrial MOCVD equipment. Review of conventional blue-white LED design and deposition parameters. Deposition of single-crystalline gallium nitride thin film on c-plane oriented sapphire substrate.   1. Non-Vacuum Deposition Techniques. Wet-casting and spin-coating.   Spray Pyrolysis. Sol-gel technology. Spin-coating. Electroplating and electrophoresis.  Blade casting, meniscus and dip coating methods. Ink-jet printing. Electro-spinning method. Langmuir Blodgett method.  Laboratory exercise: Polymer thin film preparation via spin-coating. | | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Semiconductor physics and devices*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 28 |
| ***Number of Seminar and Practical Assignment Hours*** | 4 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.habil.phys. Uldis Rogulis  Dr.phys. Aivars Vembris  Dr.phys. Vjačeslavs Kaščejevs |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to provide a review about the basic phenomena and effects in semiconductor materials with respect to their application in microelectronics and optoelectronics.  Tasks of the course:   1. To acquire the physical properties of the inorganic semiconductors and their main application possibilities; 2. To acquire the properties and theoretical description methods of the organic semiconductors, as well as prospective application fields; 3. To acquire the main semiconductor devices used in the modern electronics and microelectronics as well as the principles of their construction and operation.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Describes semiconductor materials properties; 2. Explains experimental methods used in materials research; 3. Explains semiconductor device design; 4. Describes condensed matter physics; 5. Describes materials physics;   Skills:   1. Chooses the necessary experimental equipment to characterize the properties of semiconductor materials and devices; 2. Uses theoretical models to describe the properties of semiconductor materials;   Competence:   1. Use knowledge of theoretical models for the description of properties of inorganic and organic semiconductors, as well as to use advisedly the semiconductor devices in research and practice. | |
| ***Course Plan*** | |
| 1. Semiconductor materials, energy bands in semiconductors. L2 2. Fermi level in semiconductors, carrier concentration and transport phenomena. L2 3. Electrical and galvanomagnetical effects. Thermoelectricity. L2 4. Optical properties of semiconductors. L2 5. Basic principles of organic solids state. L2 6. Electronic structure of organic materials. L2 7. Charge carrier injection, photo-generation and charge transfer process in organic solids. L2 8. Test 1. P2 9. The p-n junction and hetero-structures. L2 10. Diodes and transistors. L2 11. MOSFETs and CMOS technology. L2 12. Photodetectors and solar cells. L2 13. Light-emitting and laser diode devices. L2 14. Integrated devices in modern microelectronics. L2 15. Quantum semiconductor devices. L2 16. Test 2 P2   L – lecture, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work takes place individually and / or in small work groups.  Independent tasks:   1. To study the literature related to the course topics; 2. Using the course Moodle materials, prepare for tests; 3. Prepare for the course exam. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Test Nr.1- 25% 2. Test Nr.2- 25%   Final examination:   1. Exam (oral)- 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Types of tests | Study results | | | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | 1. Test Nr.1 | + | + | + | + | + | + | + | + | | 1. Test Nr.2 | + | + | + | + | + | + | + | + | | 1. Exam | + | + | + | + | + |  |  | + | | |
| ***Compulsory Reading List*** | |
| 1. Brütting, Ed.W. Physics of Organic Semiconductors. J.Wiley & Sons, 2005 2. Silinsh, E.A. Electronic States of Organic Molecular Crystals, Zinatne, Riga, 1977 (krieviski) 3. Silinsh, E.A., Kurik, M.V., Čapek, V. Electronic Processes in Organic Molecular Crystals. Localization and Polarization, Zinatne, Riga 1988 (krieviski). 4. Sze, S.M., Kwok, K. Ng, Physics of Semiconductor Devices, J. Wiley & Sons, 2007. 5. Šaļimova, K. Pusvadītāju fizika. Rīga, Zvaigzne, 1973, 321 lpp. 6. Vainovskis, E. Pusvadītāju radioelektronika. Rīga, Zvaigzne, 1985, 210 lpp. | |
| ***Further Reading List*** | |
| 1. Balkanski, M., Wallis, R.F. Semiconductor Physics and Applications, Oxford University Press, 2000, 512 p. 2. Enderlein, R., Horing, N.J., Fundamentals of Semiconductor Physics and Devices, World Scientific, 1996. 3. Poole Jr, C.P., Owens, F.J. Introduction to Nanotechnology, Wiley Interscience, 2003. 4. Simon, J., André, J.-J. Molecular Semiconductors. Photoelectrical Properties and Solar Cells, Springer Verlag, Weinheim, 1985 | |
| ***Periodicals and other sources*** | |
| 1. Organic Electronics, International Journal of Materials, Physics, Chemistry and Applications, Elsevier. 2. Thin Solid Films, International Journal of the Science and Technology of Condensed Matter Films, Elsevier. | |
| ***Course Content*** |  |
| ***Topic 1. Inorganic semiconductors.***  ***Lecture 1.*** (2 hours) **Semiconductor materials, energy bands in semiconductors.**  Main characteristics of semiconductors. Intrinsic and extrinsic semiconductors. Semiconductor structures. Formation of energy bands in semiconductors, wave vector, quasi-impulse. Brillouin zones. Effective mass of charge carriers.  ***Lecture 2.*** (2 hours) **Fermi level in semiconductors, carrier concentration and transport phenomena.**  Electron and hole statistics in semiconductors. Fermi level. Degenerated and non - degenerated semiconductors. Semiconductor conductivity, charge carrier mobility. Carrier scattering mechanisms.  ***Lecture 3.*** (2 hours) **Electrical and Galvano-magnetical effects. Thermoelectricity.**  Transfer phenomena in strong electric fields. Gunn effect. Zener effect. Galvanomagnetic phenomena, cyclotron resonance. Thermoelectric phenomena in semiconductors: thermo-EDS, Peltier effect.  ***Lecture 4.*** (2 hours) **Optical properties of semiconductors.**  Optical properties of semiconductors: absorption, luminescence, photoconductivity. Dember effect in illuminated semiconductor.  ***Topic 2. Organic semiconductors.***  ***Lecture* *5.*** (2 hours) **Basic principles of organic solids state.**  Organic molecules. Covalent, hydrogen, Van der Waals bonds. Energy levels of an organic molecule. Formation of electronic levels in organic solids. Molecular interaction forces in a solid. Multi - electron approximation.  ***Lecture* *6*.** (2 hours) **Electronic structure of organic materials.**  Energetic structure of polar states in organic materials. Adiabatic energy gap. Optical energy gap. Polarone Energy levels of polarons. Local electronic states in a real organic solid.  ***Lecture* *7*.** (2 hours) **Charge carrier injection, photogeneration and charge transfer process in organic solids.**  Charge carrier injection and transfer processes in organic materials. Metal-organic solid interface. Energy levels of organic solid/organic solid at the interface. Injection and transfer of charge carriers in an electric field. Photogeneration mechanisms.  **Test work No 1.**  Test work on Topics 1-7.  ***Topic 3. Semiconductor devices.***  ***Lecture 9*.** (2 hours) **The p-n junction and heterostructures.**  Semiconductor-semiconductor contact, p-n transition. Diffusion and drift current at p-n junction, p-n junction in forward and reverse bias directions. Metal and semiconductor contact. Semiconductor heterostructures.  ***Lecture 10*.** (2 hours)**Diodes and transistors.**  Semiconductor diodes, types and characteristics.  Bipolar transistors, their operation principles and characteristics.  ***Lecture 11*.** (2 hours) **MOSFETs and CMOS technology.**  Field effect transistors, their operation principles and basic characteristics. Metal-Oxide-Semionductor FETs. CMOS transistor circuits and digital logic elements.  ***Lecture 12*.** (2 hours) **Photodetectors and solar cells.**  Photoconductors and photodiodes, avalanche photodiode. Photovoltaic cells and their main characteristics.  ***Lecture 13*.** (2 hours) **Light-emitting and laser diode devices.**  Light emitting diodes, their operation principles, characteristics and technological trade-offs. Semiconductor lasers. Organic LEDs.  ***Lecture 14*.** (2 hours) **Integrated devices in modern microelectronics.**  High degree of integration of semiconductor devices. Semiconductor device and chip technology, optical and electron beam lithography. Technological overview of a microelectronics foundry.  ***Lecture 15*.** (2 hours) **Quantum semiconductor devices.**  Quantum coherence and single-electron charging effects in semiconductor nanostructures. Nanowire transistors, quantum dots, spin qubits.  **16. Test work No 2.**  Test work on Topics 9-16. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
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| ***Study Course Title*** | ***Microscopy and spectroscopy characterization methods*** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 40 |
| ***Number of Seminar and Practical Assignment Hours*** | 0 |
| ***Number of Laboratory Work Hours*** | 24 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 17.03.2021 |
| ***Course Developer*** | Dr.phys., Aleksejs Kuzmins |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The goal of the course is to promote students' understanding of modern experimental methods that are used to study the electronic and atomic structure of materials. The course gives theoretical and experimental backgrounds of diffraction, microscopy and X-ray spectroscopy characterization methods and their application in materials science.  Tasks of the course are to:   1. provide a theoretical and experimental basis on modern experimental methods, such as scanning and transmission electron microscopy, scanning probe and tunneling microscopy, X-ray and neutron diffraction, X-ray absorption spectroscopy, mass spectrometry and X-ray fluorescence spectrometry, X-ray and ultraviolet photoelectron spectroscopy; 2. provide a theoretical and experimental basis on advanced and emerging techniques; 3. comparatively analyse the common and different features of the methods and their fields of applications.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Names and describes modern experimental methods used to study the electronic and atomic structure of materials; 2. Understands fundamental principles and possible applications of electron and scanning microscopies, X-ray absorption and fluorescence spectroscopies, X-ray and ultraviolet photoelectron spectroscopies, mass spectrometry, X-ray, electron and neutron diffraction as well as new advanced and emerging techniques;   Skills:   1. Uses electron and scanning microscopes; 2. Uses X-ray diffractometers; 3. Uses X-ray fluorescence and mass spectrometers; 4. Analyses X-ray absorption spectra data analysis; 5. Analyses and interprets experimental results in the fields of electron and scanning microscopy, X-ray diffraction, X-ray fluorescence spectrometry, mass spectrometry and X-ray absorption spectroscopy;   Competence:   1. Analyses and formulates the use of electron and scanning microscopes, X-ray diffractometers, X-ray fluorescence and mass spectrometers as well as in X-ray absorption spectra data analysis. | |
| ***Course Plan*** | |
| 1. Scanning and transmission electron microscopy. L8 Ld8 2. Scanning probe microscopy. L4 Ld4 3. Scanning tunneling microscopy. L4 4. X-ray absorption spectroscopy. L4 Ld4 5. X-ray and neutron diffraction. L4 Ld4 6. Mass spectrometry and X-ray fluorescence spectrometry. L4 Ld4 7. X-ray and ultraviolet photoelectron spectroscopy. L4 8. Introduction to advanced and emerging techniques. L8   L - lecture, S - seminar, P - practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students independent work is organized individually and/or in small work groups.  Independent tasks are to:   1. study the literature related to the course topics; 2. test their knowledge using the provided materials (in the MOODLE environment); 3. formalize the results of laboratory works and present them before the exam. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. 5 laboratory work – 50%   Final examination:   1. Exam (written) – 50%   Students may take the final examination only if all intermediate tests have been taken. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment |  | |  | | Learning outcomes | | | | | | | 1. | 2. | | 3. | | 4. | 5. | 6. | 7. | 8. | | 1. Laboratory work | X | X | | X | | X | X | X | X |  | | 1. Exam |  |  | |  | |  |  |  |  | X | | |
| ***Compulsory Reading List*** | |
| 1. Egerton, R.F. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM (Springer, 2005). 2. Kuzmins, A. Materiāli kursam „Mikroskopijas un spektroskopijas pētījumu metodes”, Moodle vidē. 3. Mobilio, S., Boscherini, F., Meneghini, C. Synchrotron Radiation: Basics, Methods and Applications (Springer-Verlag, 2015). 4. Sarid, D. Scanning Force Microscopy (Oxford University Press, 1994). | |
| ***Further Reading List*** | |
| 1.sadaļa   1. Goodhew, P.J., Humphreys, J., Beanland, R. Electron Microscopy and Analysis, Third Edition 3rd Edition (Taylor & Francis, 2001). 2. Reimer, L. , Kohl, H., Transmission Electron Microscopy: Physics of Image Formation (Springer, 2008). 3. Williams, D. B., Carter, C. B. Transmission Electron Microscopy: A Textbook for Materials Science (Springer, 2009).   2.sadaļa   1. Kalinin, S. V., Gruverman, A. Scanning Probe Microscopy of Functional Materials: Nanoscale Imaging and Spectroscopy (Springer, 2010). 2. Meyer, E., Hug, H. J., Bennewitz, R. Scanning Probe Microscopy: The Lab on a Tip (Springer-Verlag Berlin Heidelberg, 2004).   3.sadaļa   1. Bhushan, B., Fuchs, H., Hosaka, S. (Eds.), Applied Scanning Probe Methods (Springer-Verlag Berlin Heidelberg, 2004). 2. Wiesendanger, R., Scanning Probe Microscopy and Spectroscopy: Methods and Applications (Cambridge University Press, 1998).   4.sadaļa   1. Bunker, G. Introduction to XAFS (Cambridge University Press, 2010) 2. Calvin, S. XAFS for everyone (CRC Press, 2013) 3. Van Bokhoven, J.A., Lamberti, C. X-Ray Absorption and X-Ray Emission Spectroscopy: Theory and Applications (Wiley, 2016). 4. Willmott, P. An Introduction to Synchrotron Radiation (John Wiley and Sons, 2011)   5.sadaļa   1. Dinnebier, R. E., Billinge, S. J. L. Powder Diffraction: Theory and Practice (RSC Publishing, 2008). 2. Kisi, E. H., Howard, Ch. J. Applications of Neutron Powder Diffraction (Oxford University Press, 2008). 3. Pecharsky, V. K., Zavalij, P. Y. Fundamentals of Powder Diffraction and Structural Characterization of Materials (Springer, 2009). 4. Suryanarayana, C., Grant Norton, M. X-Ray Diffraction: A Practical Approach (Springer, 1998).   6.sadaļa   1. Beckoff, B.,Kanngiesser, B., Langhoff, N., Vedell, R., Wolff, H. (eds.) Handbook of practical X-ray Fluorescence analysis (Springer, Berlin Heidelberg New York 2006, 863 pages). 2. de Hoffmann, E., Stroobant, V. Mass Spectrometry: Principles and Applications (3rd Edition,Wiley 2007, 489 pages). 3. Tertian, R., Claisse, F. Principles of quantitative X-ray fluorescence analysis (Heyden London, Philadelphia, Rheine, 1982, 385 pages).   7.sadaļa   1. Hofmann, S. Auger- and X-Ray Photoelectron Spectroscopy in Materials Science (Springer-Verlag Berlin Heidelberg, 2013). 2. Van der Heide, P. X-ray Photoelectron Spectroscopy: An introduction to Principles and Practices (Wiley, 2012). 3. Wagner, J. M. X-ray photoelectron spectroscopy (Nova Science Publishers, 2011).   8.sadaļa   1. Feigin, L. A., Svergun, D. I. Structure Analysis by Small-Angle X-Ray and Neutron Scattering (Springer, 1987). 2. Guo, J. X-Rays in Nanoscience Spectroscopy, Spectromicroscopy, and Scattering Techniques (WILEY-VCH, 2010). 3. Kumar, C.S.S.R. X-ray and Neutron Techniques for Nanomaterials Characterization (Springer-Verlag, 2016). 4. Reimers, W., Pyzalla, A. R., Schreyer, A., Clemens, H. Neutrons and Synchrotron Radiation in Engineering Materials Science (WILEY-VCH, 2008). 5. Willmott, P. An Introduction to Synchrotron Radiation (John Wiley and Sons, 2011) | |
| ***Periodicals and other sources*** | |
| 1.sadaļa   1. Blelocha, A., Lupini, A. Imaging at the picoscale, Materials Today 7 (2004) 42-48. DOI: 10.1016/S1369-7021(04)00570-X. 2. Vanacore, G.M., Fitzpatrick, A.W.P., Zewail, A.H. Four-dimensional electron microscopy: Ultrafast imaging, diffraction and spectroscopy in materials science and biology, Nano Today 11 (2016) 228-249. DOI: 10.1016/j.nantod.2016.04.009.   2.sadaļa   1. AFM bibliography (On request), http://nano.em.keysight.com/index.php/afm-bibliography 2. Free SPM image processing software, http://gwyddion.net/ 3. Journal of Microscopy, http://onlinelibrary.wiley.com/journal/10.1111/(ISSN)1365-2818 4. Microscopy and Analysis, http://www.microscopy-analysis.com/ 5. NT-MDT Spectrum Instruments, http://www.ntmdt-si.com/spm-principles/view/atomic-force-microscopy   3.sadaļa   1. NT-MDT Spectrum Instruments, http://www.ntmdt-si.com/spm-principles/view/constant-current-mode 2. Scanning tunneling microscopy, https://www.youtube.com/watch?v=BcgG3Cp8QQY 3. Scanning tunneling microscopy: Lecture 6, http://www.eng.utah.edu/~lzang/images/Lecture\_6\_STM.pdf   4. un 5.sadaļas   1. European Synchrotron Radiation Facility (ESRF), http://www.esrf.eu/ 2. European XFEL facility, http://www.xfel.eu/ 3. Neutron News, A Taylor & Francis Journal, http://www.tandfonline.com/ 4. Synchrotron Radiation News, A Taylor & Francis Journal. http://www.tandfonline.com/   6.sadaļa   1. Finehout, E. J., Lee, K H., An Introduction to Mass Spectrometry Applications in Biological Research, Biochem. Mol. Biol. Edu. 32, 93-100 (2004). DOI: 10.1002/bmb.2004.494032020331. 2. Mass Spectometry, http://www.spectroscopyonline.com/mass-spectrometry-13 3. NIST: Physical Mesurement Laboratory, X-Ray Form Factor, Attenuation, and Scattering Tables, https://www.nist.gov/pml/x-ray-form-factor-attenuation-and-scattering-tables 4. West, M., Ellis, A.T., Kregsamer, P., Potts, P.J., Streli, Ch., Vanhoof, Ch., Wobrauschek, P. Atomic spectrometry update. X-ray fluorescence spectrometry, J. Analytical. Atomic Spectrometry 22 (2007) 1304-1332, DOI: 10.1039/b712079f.   7.sadaļa   1. Journal of Electron Spectroscopy and Related Phenomena, https://www.journals.elsevier.com/journal-of-electron-spectroscopy-and-related-phenomena 2. NIST X-ray Photoelectron Spectroscopy Database, https://srdata.nist.gov/xps/Default.aspx 3. Surface Science Spectra, http://avs.scitation.org/journal/sss   8. sadaļa   1. European Synchrotron Radiation Facility (ESRF), http://www.esrf.eu/ 2. European XFEL facility, http://www.xfel.eu/ | |
| ***Course Content*** |  |
| 1. Scanning and transmission electron microscopy.   Introduction to microscopy and resolution limiting factors. Electron interaction with condensed matter. Fundamentals of electron microscopy. Architecture of modern SEM (Scanning Electron Microscope) and TEM (Transmission Electron Microscopy). Electron image detection systems (SE, BSE, CL, BF, DF, HAADF etc). The use of additional experimental techniques (EDX, EELS, SADP, CBED, CL). Focused ion beam (FIB) microscopy and sample preparation.  Laboratory: sample preparation for SEM and TEM, SEM imaging, EDX on SEM, TEM and HRTEM.   1. Scanning probe microscopy.   Principles behind atomic force microscopy. Different modes of operation: contact, non-contact, tapping. Derived methods: scanning near-field optical microscopy, magnetic microscopy, force modulation microscopy. Experimental settings and samples for scanning probe microscopy. Image artefacts and their sources. Methods related to scanning probe microscopy for quantitative mechanical characterization of materials.  Laboratory: surface morphology characterization using atomic force microscopy.   1. Scanning tunneling microscopy.   Introduction to STM microscopy. One-dimensional electron tunnelling. STM design and instrumentation. Topographic imaging by STM: Constant current imaging and Constant height imaging. Interpretation of STM images and artefacts. Tunnelling spectroscopy: Voltage-dependent STM imaging, Scanning tunnelling spectroscopy at constant current, Local I-U measurements at constant separation. Applications: Imaging of Semiconductors, Metals and Layered materials; Organic materials: LB films and DNS.   1. X-ray absorption spectroscopy.   Interaction of radiation with condensed matter: inelastic scattering. Local atomic structure. Pair (radial) and n-atom distribution functions. Synchrotron radiation and x-ray optics. X-ray absorption spectroscopy: theories, experiments, and applications.  Laboratory: x-ray absorption spectra analysis and structural information extraction.   1. X-ray and neutron diffraction.   Interaction of radiation with condensed matter: elastic scattering. Introduction to crystallography. Crystal structure: classification by symmetry, unit cell, Bravais lattice, Miller indices, planes and directions. Polymorphism. Bragg diffraction. Laue, rotating crystal and powder diffraction methods. Rietvield analysis. Total x-ray and neutron scattering. Pair distribution function analysis.  Laboratory: x-ray powder diffraction for crystal structure determination.   1. Mass spectrometry and X-ray fluorescence spectrometry   Basic principles of the mass spectrometry. Technical implementation of the ion sources and mass analyzers. Quadrupole, time-of-flight, ion-trap, Fourier-transform cyclotron-resonance, electromagnetic sectoring mass analysers. Mass spectrometry of the organics and inorganics. Tandem mass-spectrometers, combination with chromatography. Analysis of the spectra.  Physical principles of X-ray fluorescence. Absorption and emission of X-rays. Energy-dispersive and wavelength-dispersive X-ray spectrometry. Spatial resolution. Micro-focussing of X-rays. Elemental analysis in electron microscopy. Quantitative analysis by fundamental parameters method and by reference samples-based methods. Analysis of thin films.  Laboratory: chemical element composition determination using x-ray fluorescence analysis.   1. X-ray and ultraviolet photoelectron spectroscopy.   Physical aspects of the technique – excitation of the atom and emission of the core electrons. Technical realization of the X-ray photoelectron spectrometer (XPS) systems. Analysis of the XPS spectrum (atomic composition and chemical state). Valence band spectroscopy with XPS and UPS (ultraviolet photoelectron spectroscopy).   1. Introduction to advanced and emerging techniques.   X-ray microscopy. Photoelectron emission microscopy (PEEM). X-ray and neutron imaging. Tomography. X-ray & neutron inelastic scattering. Resonant inelastic x-ray scattering (RIXS). X-ray & neutron small angle scattering. X-ray free electron laser (XFEL). | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Optical and magnetic spectroscopy*** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 28 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** | 20 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.habil.phys. Uldis Rogulis  Dr.phys. Jurģis Grūbe |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to provide knowledge about the methods of optical and magnetic resonance spectroscopy used in the solid state research, their principles, technical aspects and application examples.  Tasks of the course are:   1. To introduce the main equipment used in the absorption and luminescence research: monochromators, spectrometers, radiation sources and detectors; 2. To introduce main magnetic resonance spectroscopy methods – EPR, NMR; 3. To introduce practical knowledge and skills in the optical and magnetic spectroscopy by performing of 5 laboratory works.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands optical and magnetic resonance spectroscopy methods; 2. Understands condensed matter physics; 3. Understands materials physics used in solid materials research;   Skills:   1. Chooses the necessary optical and magnetic spectroscopy experimental equipment for characterization of material properties; 2. Uses theoretical models to describe the optical and magnetic properties of solids;   Competence:   1. Uses the conventional models for the description of the results obtained by the optical and magnetic spectroscopy methods. | |
| ***Course Plan*** | |
| 1. Absorption spectroscopy. L2 2. Vibrational spectroscopy. L2 3. Raman scattering. L2 4. Luminescence. L2 5. Polarisation and processes. L2 6. Optical spectrometers. L2 7. Time resolved spectroscopy. L2 8. Test. P2 9. EPR – principles. L2 10. EPR – applications. L2 11. NMR – principles. L2 12. NMR – time resolved techniques. L2 13. Magneto-optical spectroscopy. L2 14. Spectroscopy of scintillators and radiation detectors. L2 15. Spectroscopy of point defects. L2 16. Test. P2 17. Laboratory work – Absorption. Ld4 18. Laboratory work – Luminescence. Ld4 19. Laboratory work – Time resolved luminescence. Ld4 20. Laboratory work – IR Fourier absorption. Ld4 21. Laboratory work – EPR. Ld4 22. Discussions on laboratory works. S6 23. Seminars. S6   L – lecture, S – seminar, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work takes place individually and / or in small work groups.  Independent tasksof the course are:   1. To study the literature related to the course topics; 2. To prepare for laboratory work; 3. To draw up laboratory work protocols; 4. Using the course Moodle materials, prepare for tests; 5. To prepare for the course exam. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. 2 practical tests - 40% 2. 5 laboratory works - 30%   Final test:   1. Exam (oral) - 30% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Types of asssment | Learning outcomes | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | | 1. 1st Test | + | + | + | + | + | + | | 1. 2nd Test | + | + | + | + | + | + | | 1. Laboratory works | + | + | + | + | + | + | | 1. Exam | + | + | + |  |  | + | | |
| ***Compulsory Reading List*** | |
| 1. Chizhik, V. I. , Chernyshev, Yu. S., Donets, A. V., Frolov, V. V., Komolkin, A. V., Shelyapina, M. G. Magnetic Resonance and Its Applications. Springer, 2014. 2. Koechner, W. Solid-State laser engineering. Springer., 2006, 742 p. 3. Kuzmany, H. Solid State Spectroscopy, Springer, 2009. 4. Smith, F.G., King, T.A., Wilkins, D. Optics and Photonics: An Introduction. John Wiley and Sons. 2007, 499 p. 5. Weil, J. A., Bolton, J. R. Electron Paramagnetic resonance, John Wiley and Sons. 2007. 6. Драго Р. Физические методы в химии, M, "Мир", 1979. 7. Марфунин А.С, "Спектроскопия, люминесценция и радиационные центры в минералах", M, Недра, 1975. | |
| ***Further Reading List*** | |
| 1. Alukers, E.D., Gavrilovs, V.V., Deičs, R.G., Černovs, S.A. Ātrie radiācijas stimulētie procesi sārmu metālu halogenīdu kristālos”, Rīga, Zinātne, 1987 (krievu val.) 2. Eaton, G. R., Eaton, S. S., Barr, D. P., Weber, R. T. “Quantitative EPR”, Springer, 2010. 3. Luščiks, Č. B., Luščiks, A. Č. Elektronisko ierosinājumu sabrukšana ar defektu rašanos cietās vielās, Maskava, Nauka, 1989 (krievu val.) 4. Spaeth, J.M., Overhof, H. Point defects in Semiconductors and Insulators, Springer, 2003. | |
| ***Periodicals and other sources*** | |
| 1. Bruker: High-performance scientific instruments and analytical and diagnostic solutions to explore life and materials at molecular level, http://www.bruker-biospin.com/brukerepr/whatiseprcontinuouswave.html 2. Zinātniskā periodika, konferenču u.c. materiāli. | |
| ***Course Content*** |  |
| **Lecture 1.** **Absorption spectroscopy** (2 hours)  Optical absorption, transmission, optical density, transition probability, oscillator strength.  **Lecture 2.** **Vibrational spectroscopy** (2 hours)  IR absorption, Fourier spectroscopy.  **Lecture 3.** **Raman scattering** (2 hours)  Principles, techniques.  **Lecture 4.** **Luminescence** (2 hours)  Photoluminescence, thermoluminescence, luminescence excitation spectra.  Quantum efficiency, CIE indexes.  **Lecture 5.** **Polarisation and processes** (2 hours)  Linear polarisation, circular dichroism, up-conversion and down-conversion, two-photon and non-linear processes.  **Lecture 6.** **Optical spectrometers** (2 hours)  Optical absorption and luminescence spectrometers. Radiation sources and detectors.  **Lecture 7.** **Time resolved spectroscopy** (2 hours)  Time resolved absorption and luminescence techniques. Luminescence kinetics.  **8. Test work No. 1** (2 hours)  Test work on topics 1-7.  **Lecture 9.** **EPR - principles** (2 hours)  Principles of the electron paramagnetic resonance (EPR).  **Lecture 10.** **EPR – applications** (2 hours)  EPR techniques, spectra examples.  **Lecture 11.** **NMR – principles** (2 hours)  Principles of the nuclear magnetic resonance (NMR).  NMR spectra, chemical shift, multiplicity.  **Lecture 12.** **NMR – time resolved techniques** (2 hours)  NMR pulse techniques.Relaxation times, magnetic resonance tomography. Multi-pulse and multi-dimensional techniques.  **Lecture 13. Magneto-optical spectroscopy** (2 hours)  Magnetic circular dichroism, Faraday rotation. Optically detected magnetic resonances.  **Lecture 14. Spectroscopy of scintillators and radiation detectors** (2 hours)  Energetic resolution and time resolved spectroscopy of scintillators. Spectroscopy of radiation detectors.  **Lecture 15.** **Spectroscopy of point defects** (2 hours)  Characterisation of colour centres and luminescence centres in solids usually requires a complex application of most of the described above optical and magnetic resonance methods.  **16. Test work No.2** (2 hours)  Test work on topics 8-15.  **17. Laboratory work – Absorption** (4 hours)  Experimental measurements on the absorption and transmission spectra, data evaluation and their interpretation.  **18. Laboratory work – Luminescence** (4 hours)  Experimental measurements on the luminescence and luminescence excitation spectra, data evaluation and their interpretation. Evaluation of the CIE characteristics.  **19. Laboratory work – Time resolved luminescence** (4 hours)  Experimental measurements on the luminescence kinetics, estimation of the quantum efficiency.  **20. Laboratory work – IR Fourier absorption** (4 hours)  IR Fourier absorption measurements and spectra interpretation.  **21. Laboratory work – EPR** (4 hours)  Experimental measurements on EPR spectra and their interpretation.  **22. Discussions on laboratory works** (6 hours)  Seminars – discussions on the laboratory works and experience.  **23. Seminars** (4 hours) | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Micro and nanofabrication of electronic and photonic devices*** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 28 |
| ***Number of Seminar and Practical Assignment Hours*** | 8 |
| ***Number of Laboratory Work Hours*** | 28 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 04.03.2021 |
| ***Course Developer*** | Dr.phys. Anatolijs Šarakovskis; Dr.sc.ing. Gatis Mozoļevskis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to gain an understanding of nanostructure and microdevice fabrication methods.  Tasks of the course are to:   1. learn introduction to cleanrooms; 2. get understanding of nano and micro fabrication technologies; 3. learn to create a fabrication procedure of multi-layer device; 4. get hands-on experiences with microdevice fabrication equipment.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Describes various micro and nano fabrication methods; 2. Describes semiconductor industry;   Skills:   1. Appliqates various microfabrication technologies in microdevice fabrication;   Competence:   1. Independently prepares, carries out and assesses fabrication procedure of microdevice. | |
| ***Course Plan*** | |
| 1. Intorduction to micro and nano fabrication. Cleanroom Technology. L4 2. Lithography. L4 3. Electron beam lithography. Surface cleaning and preparation. L4 4. Thermal Oxidation. Doping and diffusion. L4 5. Ion implantation. Wet etching. L4 6. Dry etching. Epitaxy. L4 7. Thin films, CMP, bonding, dicing, packaging. L4 8. Seminar. S4 9. Lab exercises. Ld28 10. Seminar S4   L - lecture, S - seminar, Ld - practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students in paralel to lectures prepare presentation about one of the microdevices of their choice, its working principle and fabrication procedure. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate test:   1. Presentation – 20%   Presentation describing microdevice fabrication of their choice.   1. Laboratory work – 30%   Device fabrication task and reports presentation.  Final examination:   1. Exam (oral) – 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | 1. | 2. | 3. | 4. | | 1. Presentation | x |  |  | x | | 1. Laboratory work |  |  | x | x | | 1. Exam | x | x |  |  | | |
| ***Compulsory Reading List*** | |
| 1. Ghodssi, R., Linm, P. MEMS Materials and Processes Handbook, Springer, 2011. 2. Plummer, J., Deal, M., Griffin, P. Silicon VLSI Technology: Fundamentals, Practice, and Modeling. Upper Saddle River, NJ: Prentice Hall, 2000. | |
| ***Further Reading List*** | |
|  | |
| ***Periodicals and other sources*** | |
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| ***Course Content*** |  |
| 1. **Intorduction to micro and nano fabrication. Cleanroom Technology L4**   Course overview. Introduction to CMOS processes, transistors and technology nodes. Fabs.  Cleanroom introduction. ISO standarts. Contamination, air filtering, cleanroom types and cleanroom etiquette.   1. **Lithography L4**   Principles of lithography. Positive and negative photoresists. Photomasks.  Direct write system. Focused ion beam milling. Mask aligners. Physics of resolution. Steppers   1. **Electron beam lithography. Surface cleaning and preparation L4**   Resolution limits. Electron sources. Focusing of electron beam and scanning. Electron-matter interaction and proximity effect. Process flow  Introduction to cleaning. Contamination and sources. Wet cleaning processes. Dry cleaning processes. Surface modification. Surface cleanliness metrology.   1. **Thermal Oxidation. Doping and diffusion. L4**   Silica. Basics on thermal oxidation. Oxidation furnace. Deal-Groove model. Oxidation parameters. Oxide characterization methods.  Reason for doping. Diffusion process. Drive in profiles. Atomistic mechanims of diffusion. Diffusion equipment. Diffusion characterization.   1. **Ion implantation. Wet etching L4**   Diffusion vs implantation. Implantation tool. Range and profile. Ion channeling. Collisions and stopping. Masking. Applications.  Etch anisotropy. Etching process and systems. Etching of silicon, silica, silicon nitride. Wet etch process development. Examples.   1. **Dry etching. Epitaxy L4**   Plasma basics and creation. Plasma cleaning. Sputtering and chemical etching. Chemistry of dry etching. Etching tools. Deep reactive ion etching.  Modern application of Epitaxy. Reaction rate balance, steady state. Homoepitaxy. Heteroepitaxy. Dopant incorporation and defects. Vapor phase epitaxy, MOCVD, MBE.   1. **Thin films, CMP, bonding, dicing, packaging L4**   PCV vs CVD. Thermal evaporation. Sputtering. Pulsed laser deposition. Atomic layer deposition. Plasma enhcanced chemical vapor deposition.  Wafer bonding, chemical mechanical planarization, wafer probe testing, wire bonding, dicing and packaging. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Synthesis, processing and applications of modern materials*** | |
|  | Physics and astronomy | |
| ***Credits*** | 4 | |
| ***Total Number of Contact Hours*** | 64 | |
| ***Number of Lecture Hours*** | 32 | |
| ***Number of Seminar and Practical Assignment Hours*** | 12 | |
| ***Number of Laboratory Work Hours*** | 20 | |
| ***Course Approval Date*** | 20.04.2021 | |
| ***Independent Study Hours*** | 96 | |
| ***Course Developer*** | Dr.habil.phys., Linards Skuja; Dr.phys. Guna Krieķe, Dr.phys. Marija Dunce, Dr.phys. Edgars Butanovs, Dr.phys. Aivars Vembris | |
| ***Prerequisite Knowledge*** | Fizi5108, Basics of materials physics | |
| ***Study Course Abstract*** |  | |
| The aim of the course is to give an insight in synthesis, analysis and applications of selected photonics and electronics materials. Selected are materials relevant to the assigned priority research areas in Latvia, whose studies at LU ISSP have yielded international level results and which are used in Latvian high-tech industries. Taking this course will foster the scientific careers of students by enabling them to join the actual research topics of LU scientific teams and those of their international academic and industrial partners.  Tasks of the course are to:   1. To develop understanding of the atomic structure, physical and chemical properties of ceramic, glass-ceramic and glassy materials, of their similarities and differences compared to crystalline materials; 2. To learn their synthesis methods and the main application areas; 3. To learn the material requirements for applications of glass in optical fiber waveguides, optical elements for ultraviolet range, high-power lasers, and radiation environments; 4. To develop an understanding of basic properties, synthesis methods and application of piezoelectric materials; 5. To understand the structure, electronic and optical properties of 2D layered materials, their differences as compared to 3D materials, and their applications; 6. To learn the electronic structure of organic semiconductors and their similarities and differences to inorganic semiconductors, to understand their operation of organic photonic and electronic devices.   Languages of instruction are Latvian and English. | | |
| ***Learning Outcomes*** |  | |
| Knowledge:   1. Names ceramic, glass-ceramic, glassy and amorphous materials; 2. Describes phase transitions in 1-, 2-, and 3-component systems by phase diagrams; 3. Describes ceramic materials: superplastic, self-healing, transparent, piezoelectric and bio- ceramics, their properties and synthesis methods; 4. Explains main theories of glass structure, types of glasses, glass-ceramics and their basic synthesis methods; 5. Describes glassy silicon dioxide, its basic properties and production methods, its applications in optics, photonics and microelectronics; 6. Describes optical fiber waveguides, their main operation principles, materials and applications; 7. Names layered 2-D Van-der-Waals materials, their atomic and electronic structure, their properties and applications; 8. Names synthesis and characterization methods of layered 2-D Van-der-Waals materials, methods for building of photonics and electronic devices based on them; 9. Describes electronic properties of organic materials, their applications in electronics, organic transistors, thermoelectric generators and liquid crystals; 10. Names applications of organic materials in photonics, organic light emitting diodes (OLED), lasers, electro-optical modulators and solar cells;   Skills:   1. Analyses the structure, phase and chemical element content by X-ray diffraction; 2. Applicates luminescence-based investigation methods; 3. Evaluates principles of differential thermal analysis and its application for phase transition characterization; 4. Formulates aboratory-level synthesis methods of ceramic materials; 5. Analyses elemental content of materials by X-ray fluorescence (XRF) method; 6. Applicates dielectric-loss measurement method for ferroelectric ceramics; 7. Applicates optical microscopy, scanning electron microscopy, atomic force microscopy; 8. Fabricates thin films by spin-coating and thermal evaporation methods, working techniques in controlled-atmosphere (glove-box) environment; 9. Evaluates multimode optical fiber waveguides and their application in spectroscopy; 10. Fabricates and characterises organic nanowires;   Competence:   1. Recognises and assesses general synthesis methods of ceramic, glassy, 2-D and organic materials; 2. Recognises and assesses basic methods necessary for characterization of structure, morphology, elemental content, optical and electronic properties of solid state materials; 3. Analyzes and assesses inorganic and organic materials in conjunction with their practical applications in electronic and photonic devices. | | |
| ***Course Plan*** | | |
| 1. Ceramics materials: An introduction. L2 2. Synthesis and processing methods of ceramics. L2 3. Modern applications of ceramics: Super-plastic, self-healing, transparent and bio-compatible ceramic materials. L2 4. Structure of glasses. L2 5. Synthesis methods of glasses and glass-ceramics. L2 6. Types of ferroelectric materials, their characteristic properties and applications. L2 7. Glassy SiO2 and the related glasses. L2 8. Properties and applications of SiO2 materials. L2 9. Introduction in the physics and applications of fiber optic waveguides. L2 10. Fabrication and characterization of ferroelectric ceramics (Part 1 – fabrication). Ld2 11. Characterization of optical fiber waveguides, their applications in spectroscopy. S2 12. Fabrication and characterization of ferroelectric ceramics (Part 2 – measurements). Ld2 13. Fabrication and characterization of luminescent glass-ceramics. Ld4 14. Test on topics 1-13. S2 15. Introduction to layered VdW materials. L2 16. Synthesis of layered VdW materials. L2 17. Characterization of layered VdW materials. L2 18. Applications of layered VdW materials in electronics and photonics. L2 19. Fabrication of devices based on layered VdW materials. L2 20. Exfoliation and characterization of layered VdW materials. Ld4 21. Introduction to electronic properties of organic materials. L2 22. Applications of organic materials in photonics. L2 23. Fabrication of organic light emitting diode (OLED). Ld4 24. Fabrication and characterization of polymer nanofibers. Ld4 25. Test on topics 15-24. S2 26. Seminar on lab works, their examination and approval. S2 27. Seminar on lab works, their examination and approval. S2 28. Seminar on lecture course. S2   L – lecture, S – seminar, P - practical work | | |
| ***Characterization of students' independent work organization and tasks*** | | |
| The independent work of studentsw is organized individually and, in case of laboratory works, in small work –groups (typically, pairs of students).  Tasks for independent work:   1. Literature studies on properties of materials discussed in the course and of materials related to them; 2. Preparation to tests and seminars; 3. Get acquainted with operation principles of instrumentation used in lab works and with their parameters and options offered by them; 4. By using the web resources, to find examples of practical applications, based on the materials discussed in the course, to perform an analysis of their merits and disadvantages. | | |
| ***Requirements for Awarding Credits*** | | |
| Intermediate tests:   1. 2 written tests on topics (1-13) and (15-24) - 30% 2. 5 approved laboratory works - 40%   Final examination:   1. Exam (orally) - 30%   Any mark must be no less than "4" in 10 point scale. The final mark is formed by test marks (2×15%), lab work marks (5×8%) and oral exam (1× 30%). | | |
| ***Criteria for Evaluation Learning Outcomes*** |  | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **Types of tests** | **Learning outcomes** | | | | | | | | | | | | | | | | | | | | | | | |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | 1. 1st test | + | + | + | + | + | + |  |  |  |  |  |  |  |  |  |  |  |  | + |  | + | + | + | | 1. 2nd test |  |  |  |  |  |  | + | + | + | + |  |  |  |  |  |  |  |  |  |  |  | + | + | | 1. 1st lab work | + | + |  |  |  |  |  |  |  |  | + | + | + | + |  |  |  |  |  |  |  | + |  | | 1. 2nd lab work |  |  |  |  |  |  |  |  |  |  | + |  |  | + | + | + |  |  |  |  |  | + | + | | 1. 3rd lab work |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | + |  |  |  |  | + |  | | 1. 4th lab work |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | + | + |  | + |  | + |  | | 1. 5th lab work |  |  |  |  |  |  |  |  |  |  |  | + |  |  |  |  |  | + |  |  |  | + | + | | 1. Exam | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | | | |
| ***Compulsory Reading List*** | | |
| 1. Avouris, P., Heinz, T. F. , Low, T. 2D Materials, Cambridge University Press, 2017 2. Brütting, Ed. W. Physics of Organic Semiconductors. J.Wiley & Sons, 2005 3. Dragoman, M., Dragoman, D. 2D Nanoelectronics: Physics and Devices of Atomically Thin Materials, Springer, 2016 4. Kashyap, R. Fiber Bragg gratings. 2nd edition, Academic Press, 2010. 5. Kursa materiāli Moodle vidē. 6. Lines, M.E., Glass, A.M. Principles and Application of Ferroelectrics and Related Materials, Clarendon Press, Oxford, 1977. 7. Rao, C. N. R., Waghmare, U. V. 2d Inorganic Materials Beyond Graphene, 8. Shelby, J. E.. “Introduction to Glass Science and Technology”, (2nd ed.). Cambridge: Royal Society of Chemistry, 2005. 9. Silinsh, E.A., Kurik, M.V., Čapek, V. Electronic processes in organic molecular crystals. Localization and polarization, Zinatne, Riga 1988 10. Simon, J., André, J.J. Molecular Semiconductors. Photoelectrical Properties and Solar Cells, Springer Verlag, Weinheim, 1985 11. Tredgold, R. Order in Thin Organic Films, Cambridge University Press, Cambridge, 1994 12. World Scientific, 2017 13. Yin, Q., Zhu, B., Zeng, H. “Microstructure, Property and Processing of Functional Ceramics”. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010. 14. Yin, S., Ruffin, P.B., Yu, F.T.S. eds., “Optical fiber sensors” , CRC Press, Taylor&Francis 2008. | | |
| ***Further Reading List*** | | |
| 1. Fokine, M. Photosensitivity, chemical composition gratings, and optical fiber based components, Ph.D. thesis, KTH Royal Institute of Technology, Stockholm 2002. 2. Kittel, Ch. Introduction to Solid State Physics, 8th edition, John Wiley and Sons, 2005. 3. Mendez, A., Morse, T.F. Speciality optical fibers handbook, Elsevier 2007. 4. Ter-Mikirtychev, V. Fundamentals of Fiber Lasers and Fiber Ampliﬁers, Springer Series in Optical Sciences vol.181, Springer, Heidelberg, N.Y., Dordrecht, London 2014. | | |
| ***Periodicals and other sources*** | | |
| 1. Canning, J. Fibre gratings and devices for sensors and lasers. Laser & photonics reviews, v.2, No4, p.275-89(2008). 2. Choi, W., Choudhary, N., Han, G. H., Park, J., Akinwande, D., Lee, Y.H. Recent development of two-dimensional transition metal dichalcogenides and their applications, Materials Today, 20, 116-130, 2017 3. Duong, D. L., Yun, S. J., Lee, Y. H. Van der Waals Layered Materials: Opportunities and Challenges, ACS Nano, 11, 12, 11803–11830, 2017. 4. Girard, S., Kuhnhenn, J.; Gusarov, *et al.*, Radiation Effects on Silica-Based Optical Fibers: Recent Advances and Future Challenges. IEEE Trans. Nucl.Sci., v.60, No3 2015-2036(2013). 5. Gong, C., Zhang, Y., Chen, W., Chu, J., Lei, T., Pu, J., Dai, L., Wu, C., Cheng, Y., Zhai, T., Li, L., Xiong, J. Electronic and Optoelectronic Applications Based on 2D Novel Anisotropic Transition Metal Dichalcogenides, Advanced Science, 4, 1700231, 2017 6. Hill, K.O., Meltz, G. Fiber Bragg Grating Technology Fundamentals and Overview, J.Lightwave Technol. v.15, p.1263-1276 (1997). | | |
| ***Course Content*** | | |
| 1. **Ceramics materials: An introduction (L2)**   The origin and development of ceramic materials. Traditional and functional ceramics, the plurality of ceramic materials. Microstructure, ceramic grains, grain boundaries. Phase equilibria in ceramic systems.     1. **Synthesis and processing methods of ceramics (L2)**   The preparation of the raw materials. The traditional and contemporary techniques of formation of ceramic materials. Sintering and grain growth.   1. **Modern applications of ceramics: Super-plastic, self-healing, transparent and bio-compatible ceramic materials (L2)**   Definitions of stress and strain. Super-plastic ceramics: superplasticity, grain sliding and re-crystallization. Applications of superplastic ceramics. Biomaterials: the main requirements, bio-inert, bio-compatible, bio-resorbable ceramic materials. Self-healing ceramic materials: principle of operation, applications. Transparent ceramics materials: light scattering in ceramics, synthesis methods, applications.   1. **Structure of glasses (L2)**   Comparison of single crystals, polycrystals and glasses. Classification of glasses. Structrural theories of glass formation. Glass-forming elements – glass-formers and modificators. Crystallization of glasses, homogeneous and heterogeneous formation of nucleation sites, crystal growth.   1. **Synthesis methods of glasses and glass-ceramics (L2)**   Melting of glass: raw materials, thermal processing, homogenization of melt, methods of melt formation. Sol-gel method: raw-materials, synthesis process, application. Methods of glass-ceramics synthesis, their applications.   1. **Fabrication and characterization of luminescent glass-ceramics (LB4)**   Calculation of the glass composition, melting of glass, characterization of glass thermal properties by differential thermal analysis (DTA), crystallization of glass, analysis of the crystalline phases by X-ray diffraction (XRD), comparison of the optical properties of glass and glass-ceramics.   1. **Glassy SiO2 and the related glasses (L2)**   Glassy SiO2 and related materials, their peculiar role in the physics of disordered materials. Structure, its relation to crystalline polymorphs od SiO2, topological disorder. Optical, mechanical and electric properties. Industrial methods of synthesis of super-pure SiO2 glass. Overview of the most important applications of SiO2 glasses: optical elements, thin films, optical fibers, nanoparticles, nano- and mesoporous materials. Role of point defects and impurities in applications of SiO2.. Diffusion in glass, role of hydrogen.   1. **Properties and applications of SiO2 materials (L2)**   Factors governing the ultraviolet (UV) transmission of glasses. Applications in UV photolithography, high-power laser optics. Multiphoton absorption, self-focusing. Femtosecond laser effects and their application for persistent long-term information recording. The fundamental optical absorption edge of crystalline and glassy SiO2. Urbach and Tauc rules. The effects of glassy disorder and phonons on the fundamental absorption edge. The increase of the optical transparency by fluorine doping.   1. **Introduction in the physics and applications of fiber optic waveguides (L2, S2)**   Insight into the historic development of optical waveguides. Conditions for propagation of light into waveguide. Numerical aperture. Waveguide modes. Single-mode and multimode light guides. Material and waveguide spectral dispersion. Optical fibers waveguides for communications, their most important parameters. Advances in the production technologies. Origins of the losses and methods of their reduction. Photoinduced Bragg gratings and their application in signal filtering. The physical mechanisms of the writing of photoinduced grating. Nanostructures in waveguides. Photonic crystal fibers. Optical nanowires. Applications beyond communications. Optical fibers for material processing, medicine, nuclear energy and space applications. Optical fibers as sensors. Optical fibers in analytical instrumentation. Optical fiber production in Latvia and their application segments. Seminar in laboratory: coupling of light into single-mode and multimode fibers. Speckles. Cleaving of fibers. Evaluation of numerical aperture. Measurement of spectral losses in the near infrared to UV spectral range, identification of their origins.     1. **Ferroelectric materials: Products and applications ( L2)**   Differences between piezoelectric, pyroelectric and ferroelectric (segnetoelectric) materials. Variety of ferroelectric materials. The practically most important properties of ferroelectrics: dielectric, electromechanical, thermoelectric and electro-optical properties. Examples of ferroelectric material applications, the main material parameters relevant to each application. Ultrasound sensors, actuators, microelectromechanic (MEMS) systems, memory cells, infrared sensors, electro-optical devices.   1. **Fabrication and characterization of ferroelectric ceramics (LB4)**   Fabrication of ferroelectric ceramics: calculation of the amount of raw materials, their weighing, mixing, placing in furnace, programming of temperature regimes. Preparation of the obtained ceramics samples: sawing, grinding, polishing, thermal etching. Characterization: X-ray diffraction, visualizing grains by scanning electron microscopy (SEM), elemental content by X-ray fluorescence, dielectric permeability and its temperature dependence.   1. **Introduction to layered Van-der-Waals materials (L2)**   Atomic structure of layered materials. Van-der-Waals (VdW) and covalent bonds. Crystalline structures. Electronic structure of graphene and transition metal dichalcogenides (TMD's). Electrical, optical and mechanical properties. Defects of crystalline lattice and doping.   1. **Synthesis of layered Van-der-Waals materials (L2)**   Synthesis of single crystals: chemical vapor deposition. Synthesis of thin films and monolayers: chemical vapor deposition (CVD), pulsed laser deposition (PLD), molecular beam epitaxy (MBE), synthesis from metal and oxide layers. Physical and chemical exfoliation.   1. **Characterization of layered VdW materials (L2)**   Raman spectroscopy, X-ray diffraction, optical spectroscopy and microscopy, scanning and transmission electron microscopy, atomic force- and scanning probe tunneling microscopy, measurements of charge carrier mobility.   1. **Applications of layered VdW materials in electronics and photonics (L2)**   Conductive electrodes, field-effect transistors, negative resistance (tunneling) diodes, photodetectors, gas sensors, pressure sensors, piezosensors, solar cells, DNS sequencers. Problems and perspectives.   1. **Fabrication of devices based on layered VdW materials (L2)**   Fabrication of field-effect transistors based on 2D materials. Wet and dry exfoliation, CVD and PLD synthesis. Photolithography and formation of contacts. Ink-jet printing, characterization of devices.   1. **Exfoliation and characterization of layered VdW materials (LB4)**   Dry exfoliation of highly-oriented pyrolytic graphite (HOPG) and transition metal dichalcogenides (TMD). Measurement of the layer thickness by optical and atomic force microscopies.   1. **Introduction to electronic properties of organic materials (L2)**   The history orf organic semiconductors. Organic molecules. Classification of organic compounds and their structures. Electrical and optical properties of organic materials, their comparison to inorganic materials. Energy levels and charge carrier transport in organic materials. Organic field-effect transistors. Solar cells. Thermoelectric effect and thermoelectric generators. Liquid crystals.   1. **Applications of organic materials in photonics (L2).**   Non-linear optical effect. Electro-optical modulator. Stimulated light emission in organic materials. Organic solid state laser. Electroluminescence. Light-emitting diodes.     1. **Fabrication of organic light emitting diode (OLED) (LB4)**   Fabrication and characterization of OLED. structure. It involves deposition of multiple necessary layers on glass substrate having transparent electrode layer. In the process, both "wet" and dry (vacuum evaporation) deposition methods will be employed. The optical and electrical properties of the fabricated OLED will be determined.   1. **Fabrication and characterization of polymer nanofibers (LB4)**   Preparation of polymer nanofibers using electro-spinning techniques. The dependence of fiber size on electrospinning process parameters and on the concentration of the polymer solution will be studied. The morphology of the nanofiber samples will be investigated by scanning electron microscopy. | | |
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**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Introduction to computational methods in material research*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 13 |
| ***Number of Seminar and Practical Assignment Hours*** | 2 |
| ***Number of Laboratory Work Hours*** | 17 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 17.03.2021 |
| ***Course Developer*** | Dr.phys. Dmitrijs Bočarovs, Mg.chem. Aleksandrs Platoņenko, Mg.chem. Andrejs Česnokovs un Oļegs Lisovskis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to introduce students to the modern software for atomic-level solid state studies. Within this course the capabilities and constraints of different programs for simulating material properties and processes are considered, and the influence of selected computational scheme and method on the modeling result is shown. Lectures present the nature and physical meaning of the methods used, while during practical work students independently model crystalline structures, surfaces and nanoobjects, obtaining information about their properties, which can be compared with experimental data. In addition, students meet tools for processing and visualizing the results.  Tasks of the study course are to:   1. introduce students to the density functional method and other methods of quantum chemistry; 2. teach the use of use computing (CRYSTAL, GAUSSIAN et. al.) and visualization (VESTA, VMD) computer codes; 3. show how to use Linux shell; 4. teach how to develop solid state calculation models, prepare input data for computing; programs and process the obtained results.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands methods of quantum solid state chemistry widely used in modern science as well as the limitations of these methods; 2. Defines the nature of the different computing methods and the inter-differences between them; 3. Describes basic principles of modelling and requirements to input data;   Skills:   1. Uses computing (CRYSTAL) and visualization (VESTA, VMD) computer codes; 2. uses the crystallographic databases and the information from the databases to prepare input files; 3. Uses Linux basic commands; 4. Composes input data for computing programs and process the obtained results;   Competence:   1. Independently chooses a particular method for solving a given task consciously; 2. Analyzes and interprets data obtained in calculations. | |
| ***Course Plan*** | |
| 1. Introduction. Data processing, visualisation and presentation, work in Linux environment. L1 Ld1 2. Crystallography databases, crystallographic structures depiction using free software (VESTA, VMD). L2 Ld2 3. Ab initio: Hartri-Fock method, LCAO, DFT. L2 4. CRYSTAL, VASP, GAUSSIAN codes. Ld2 5. Basis sets, exchange-correlation functionals, bulk properties, DOS, band structure. Ld2 6. Ab initio: pseudopotentials, plane-waves. L2 7. Bulk properties, elastic constants, phonons (IR, Raman spectra). Ld2 8. Defects, supercell, k-points. Ld2 9. Seminar. S2 10. 0D, 1D nanoobjects (nanotubes, nanowires, nanoparticles). L2 Ld2 11. 2D materials, surfaces, adsorption, interfaces. L2 Ld2 12. Molecular dynamics (Gulp, CP2K codes). L2 Ld2   L - lecture, S - seminar, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| During the course students work independently on computational laboratory assignments. Laboratory assignments are executed both during class and independently. Exercise set and each lab assignment is graded on a scale from 0 to 10. Successful completion of the laboratory assignments is a prerequisite for taking part in the exam. | |
| ***Requirements for Awarding Credits*** | |
| To complete the course, all listed practical works must be completed and reported. Each work is graded; these grades affect the final mark. To get a full score, a report on a practical work must include problem statement, correctly presented details of calculations, their results and conclusions. At the end of the term there is an oral exam.  Intermediate tests:   1. 8 laboratory works - 80%,   Final examination:   1. Exam (oral) - 20%. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | | 1. Laboratory works | x | x | x | x | x | x | x | x |  | | 1. Exam | x | x | x |  |  |  |  |  | x | | |
| ***Compulsory Reading List*** | |
| 1. Dovesi, R., Saunders, V.R., Roetti, C., Orlando, R., Zicovich-Wilson, C.M., Pascale, F., Civalleri, B., Doll, K., Harrison, N.M., Bush, I.J., D’Arco, Ph. , Llunell, M., Causá M., Noël, Y. CRYSTAL17 User’s Manual, University of Torino, 2017. 2. Evarestov, R.A. Quantum chemistry of solids. Springer-Verlag Berlin Heidelberg 2007. 3. Gale, J.D. GULP manual, Nanochemistry Research Institute, Department of Chemistry, Curtin University, 2016. 4. Kantorovich, L. Quantum Theory of the Solid State: An Introduction, Springer, 2004. | |
| ***Further Reading List*** | |
| 1. CP2K project homepage, <https://www.cp2k.org/> 2. Бандура А.В., Эварестов Р.А. Неэмпирические расчеты кристаллов в атомном базисе с использованием интернет-сайтов и параллельных вычислений, СПб.: С.-Петерб. ун-т, 2004. — 228 с. | |
| ***Periodicals and other sources*** | |
| 1. Bilbao Crystallographic Server, http://www.cryst.ehu.es/  2. Crystallography Open Database, http://www.crystallography.net/ | |
| ***Course Content*** |  |
| 1. Introduction, course syllabus. Getting acquainted with Linux shell. Data processing and data visualisation software; 2. Crystallography databases. \*.cif and \*.xyz file formats; 3. Visualisation of crystalline structures using VESTA and VMD; 4. Introduction to simulations from first-principles (Ab initio): Hartree-Fock method, linear combination of atomic orbitals (LCAO), density functional theory (DFT); 5. Ab initio software. Preparing inputs, calculating properties of molecules, analysis and processing of the results; 6. Basis sets, exchange-correlation potentials. Adjustment and comparison of numerical parameters. Calculating bulk properties of selected crystalline compounds. One-electron properties: density of states, band structure; 7. Ab initio methods and approximations: pseudopotentials, plane waves; 8. Calculating bulk properties of selected crystalline materials. Elastic constants, dielectric tensor. Calculating phonons: infrared and Raman spectra; 9. Modelling defects with the supercell approach. F-centres, substitution defects, interstitials; 10. Seminar: evaluation of laboratory works; 11. 0D, 1D nanoobjects. Nanotubes and nanowires. 0D un 1D symmetry groups. Nanoobjects’ modelling specifics. 3D—1D transformation; 12. Modelling nanoobjects; 13. Surfaces, 2D objects, interfaces and the related processes; 14. Modelling surfaces. Adsorbtion. Interfaces; 15. Molecular dynamics: the outline, scope and limitations; 16. Molecular dynamics: a computational problem. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Introduction to symmetry of solids*** |
|  | Physics and astronomy |
|  |  |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 22 |
| ***Number of Seminar and Practical Assignment Hours*** | 10 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 17.03.2021 |
| ***Course Developer*** | Dr.phys. Dmitrijs Bočarovs, Dr.rer.nat. Aleksandrs Sorokins, Mg.chem. Andrejs Česnokovs, Marija Isupova |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of this course is to introduce students to the basic concepts of crystallography, show the relationship between the structure of crystals, their symmetry and their physical and chemical properties, as well as to form an understanding of the group theory and its use in describing properties of solids.  Tasks of the course are to:   1. introduce students into group theory; 2. show how the symmetry of crystals can be described using mathematical formalism of group   theory;   1. become acquainted with the relationship between symmetry properties and point and space   groups;   1. teach students how to use crystallographic databases and related programs; 2. understand the possibilities of describing the macroscopic properties of solids using group   theory approaches.  Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands the basic concepts of crystallography as well as knows about crystal systems, crystal families, lattice systems and 32 crystal classe; 2. Knows about the symmetry operations and symmetry elements; 3. Describes basic principles of group theory;   Skills:   1. Uses crystallography databases and International Tables for Crystallography; 2. Determines the space groups of a different compounds as well as the Wyckoff positions of the individual atoms.   Competence:   1. Predicts the macroscopic properties of solids using group theory approaches. | |
| ***Course Plan*** | |
| 1. Introduction. Basic symmetry elements and operations. Symmetry of molecules. L2 2. Mathematical basis for group theory. L2 3. Basic symmetry elements and operations. Symmetry of molecules. Mathematical basis for group theory. P2 4. Mathematical basis for group theory. L1, P1 5. Mathematical basis for group theory. L1 P1 6. Use of group theory solving physical problems. Molecular vibrations. L1 P1 7. Test. P2 8. Symmetry of crystals. Crystallography. L2 9. Symmetry of crystals. Crystallography. L2 10. Symmetry of crystals. Crystallography. L1 P1 11. Symmetry of crystals. Crystallography. L2 12. Classification of symmetry groups for solids. L2 13. Crystallographic databases. Structure of some important structure types. L1 P1 14. Use of group theory solving physical problems. L2 15. Use of group theory solving physical problems. L2 16. Use of group theory solving physical problems. L1 P1   L - lecture, S - seminar, P - practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students work independently on:   1. analysis of literature related to the study course topics; 2. homework; 3. test.   Homework and test is graded on a scale from 0 to 10. Successful completion of the homework and test is a prerequisite for taking part in the exam. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:  1. one test work in the semester middle - 25%  2. home works - 25%  Final examination:  3. Exam (oral) - 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Homeworks | + | + | + | + | + | + | | 1. Test |  | + | + |  |  | + | | 1. Exam | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Evarestov, R. A., Smirnov, V. P. Site symmetry in crystals, Theory and Applications. Springer-Verlag Berlin Heidelberg, 1997, 280 p. 2. Evarestov, R.A. Quantum chemistry of solids. Springer-Verlag Berlin Heidelberg 2007, 557 p. 3. Jacobs, P. W. M. Group theory with applications in chemical physics. Cambridge University Press, 2005, 507 p. 4. Jaunbergs, A. Cietvielu teorijas pamati. Simetrijas teorija. LVU, 1982. Simetrijas grupas LVU, Rīga, 1983. 5. Sedmalis, U., Šperberga, I. Kristalogrāfija un kristālķīmija. Rīga, RTU Izdevniecība, 2006, 213 lpp. 6. West, A. R. Solid state chemistry and its applications. Wiley-Blackwell, 2014, 584 p. | |
| ***Further Reading List*** | |
| 1. Шаскольская, М.П. Кристаллография. М.: Высшая школа, 1984 2. Эллиот, Дж., Добер, П. Симметрия в физике.Т.1. Мир, М., 1983 3. Atkins, P., de Paula, J. Physical Chemistry, Oxford University Press, 2010 | |
| ***Periodicals and other sources*** | |
| 1. Bilbao Crystallographic Server, http://www.cryst.ehu.es/ | |
| ***Course Content*** |  |
| 1. Introduction. Aims and tasks of the course. Basic symmetry elements and operations: identity, symmetry planes, inversion center, rotation axes, inversion axes. Determination of the group of the molecule. 2. Mathematical basics of group theory. Mathematical definitions of a group. Group examples. Subgroups. Group algebra. Multiplication tables. Groups of matrixes. Groups of rotations in two dimensions. 3. Mathematical basics of group theory. Group of permutations. Group generators. Direct product of two groups. Conjugation. Conjugacy classes. 4. Mathematical basics of group theory. Matrix representation of symmetry operations. Characters. Representations of the group. Reducible and irreducible representations: 5. Mathematical basics of group theory. The Great orthogonally theorem and irreducible representations. Character tables. 6. Mathematical basics of group theory. Molecular vibrations. IR spectra. Raman spectra. 7. Symmetry of crystals. Neumann’s principle, Curie’s principle. 8. Symmetry of crystals. Basic laws of crystallography. Lattice. Unit cell. Classification of crystals by singonies and crystal systems. Miller indices. Bragg law. Quasicrystals. 9. Symmetry of crystals. Crystallographic point groups. The use of point groups in crystallography. Designations of crystallographic point groups. 32 crystallographic space groups. Additional symmetry operations in crystals: screw axis and Glide reflections. Translation group, Bravais lattices and space groups. Crystallographic cell. Symmetry space group. 10. Symmetry of crystals. Fractional coordinates. Wyckoff positions. 11. Symmetry of crystals. Symmetry and structure of molecules, crystals, surfaces, nanotubes and nanowires. Crystalographic databases. Crystal structure visualization tools. Structure and search of structures of common crystals (perovskite, fluorite, sphalerite, spinel, wurtzite , rutile, etc.) in databases. 12. Symmetry of crystals. Level splitting in a crystalline field. Optical spectra. Jahn-Teller effect. 13. Use of group theory solving physical problems. Reciprocal lattice, Brillouin zone. Star of the wave vector. Reductive and irreversible representations of point, translational and spatial groups. 14. Use of group theory solving physical problems. 15. Formation of band structure, phonon dispersion curves. 16. Use of group theory solving physical problems. Ideal and non-ideal crystals. Types of defects. Group theory and quantum mechanics. Use of group theory in defect calculations. Application of group theory in calculations of macroscopic properties of the crystals. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Electrical characterisation of materials*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 4 |
| ***Number of Seminar and Practical Assignment Hours*** | 4 |
| ***Number of Laboratory Work Hours*** | 24 |
| ***Course Approval Date*** | 04.03.2021 |
| ***Independent Study Hours*** | 48 |
| ***Course Developer*** | Dr.phys. Kaspars Pudžs, Dr.phys. Ēriks Birks |
| ***Prerequisite Knowledge*** | Fizi1015, Heat and Structure of Matter  Fizi2019, Electromagnetism  Fizi3007, Methodes and techniques for physical measurements  Fizi4010, Basics of the Solid State  Fizi5084, Inorganic and organic semiconductors: physics and applications |
| ***Study Course Abstract*** |  |
| The aim of the course is to provide students with comprehension about characteristic electrical, electromechanical and thermoelectrical properties of real ferroelectrics and semiconductors, which are important for research and application, as well as let them acquire methods of measurements of the considered properties.  Tasks of the course are:   1. get acquainted with the most relevant properties of ferroelectric materials, acquire main experimental methods of research, to measure and describe such properties in the case of a particular ferroelectric material; 2. clarify reasons, responsible for appearance of electrocaloric effect and to perform experimental study of this effect; 3. get acquainted with charge transport mechanisms in semiconductors and to perform measurements of parameters, characterising charge transport in thin film of a particular semiconducting material. To study the role of temperature on charge transport processes; 4. get acquainted with the methods of charge mobility measurements and with restrictions of such methods in the case of semiconducting thin films, as well as to measure charge mobility in organic and inorganic thin films; 5. get acquainted with thermoelectric effects and parameters which characterise these effects, as well as to perform measurements of the Seebeck coefficient and electrical and thermal conductivity in a semiconducting thin film.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Names the most important physical properties of ferroelectrics and semiconductors; 2. Understands the nature of electrical properties of ferroelectrics and semiconductors;   Skills:   1. Performs measurements of relevant electrical properties of ferroelectric and semiconducting compositions; 2. Formulates requirements for organisation of such experiments; 3. Analyses and interprets obtained experimental results;   Competence:   1. Understands the most important physical properties of ferroelectrics and semiconductors. | |
| ***Course Plan*** | |
| 1. Introduction in the covered by course experimental methods of study of ferroelectrics. L2 2. Determination of the dielectric properties and the piezoelectric coefficients in ferroelectrics. Ld4 3. Determination of the field induced strain and polarisation hysteresis loops in ferroelectrics. Ld4 4. Determination of the electrocaloric effect in ferroelectrics by the direct method. Ld4 5. Introduction in the covered by course experimental methods of study of semiconductors. L2 6. Determination of electrical properties of semiconducting thin films by “van der Pauw” method. Ld3 7. Determination of the thermoelectrical properties in semiconducting thin films. Ld3 8. Determination of mobility of charge carriers by “Time of flight” method. Ld3 9. Determination of surface potential and work function with Kelvin probe. Ld3 10. Presentation of experiments included in course. P4   L - lecture, S - seminar, P - practical work, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| 1. To study compulsory and recommended literature of study course. 2. To acknowledge theoretical background and work process to complete laboratory work. | |
| ***Requirements for Awarding Credits*** | |
| All laboratory works (totally 7), planned in course, have to be completed and in two weeks after completion of particular work presented, showing understanding of the measured properties and the used experimental methods. Every work is evaluated by lecturer with a single mark, which reflects knowledge by student of particular topic and quality of performed work. All marks have to be not below “4”. In seminar after whole program is completed, every student presents one particular work on choice of lecturer which is also evaluated by a single mark. The total mark is an averaged value over the all obtained particular marks (3 marks for works on ferroelectrics, 4 marks for works on semiconductors, 1 mark for presentation).  Intermediate tests:   1. Presentations of all 7 laboratory works - 88%   Final examination:   1. Exam (oral) - 12% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. 1-7. laboratory work | X | X | X | X | X |  | | 1. Oral exam | X | X | X | X | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Lines, M.E., Glass, A.M. Principles and Application of Ferroelectrics and Related Materials, Clarendon Press, Oxford, 1977 2. Silinsh, E.A. Organic Molecular Crystals, Their Electronic States, Springer Verlag, Heidelberg, 1980 | |
| ***Further Reading List*** | |
| 1. Kittel, Ch. ntroduction to Solid State Physics, 8th edition, John Wiley and Sons, 2005 2. Nye, J.F. Physical properties of crystals, Clarendon Press, Oxford, 1985 3. Rolovs, B. Termodinamika un statistiskā fizika, Zvaigzne, Rīga, 1967 | |
| ***Periodicals and other sources*** | |
|  | |
| ***Course Content*** |  |
| 1. Important properties of ferroelectric materials, their dependence on temperature and electric field. Comprehension of ferroelectric relaxors, their most characteristic properties. General characterisation of measurement methods of electrical properties of ferroelectrics. Overview of laboratory works. 2. Measurement of dielectric permittivity of ferroelectric material in dependence on temperature by impedance analyser in frequency range 100 Hz-1 MHz. Mechanisms of dielectric dispersion. Direct and inverse piezoelectric effect. Measurement of direct piezoelectric effect by d33- meter. Measurement of piezoelectric coefficient d31 and electromechanical coupling factor by resonance-antiresonance method. 3. Simultaneous measurement of field induced strain and polarisation of ferroelectric material by Michelson interferometer and Sawyer-Tower circuit. Contribution of domains in total change of polarisation. Intrinsic and extrinsic piezoelectric effects. Relation between piezoelectric effect and electrostriction. 4. Relation between pyroelectric and electrocaloric effect. Maxwell relations, direct and indirect study of electrocaloric effect. Temperature dependence of remnant polarisation, its reversible and irreversible part. Study of electrocaloric effect in ferroelectric material by direct method. Electrocaloric effect at field induced 1st order phase transition, latent heat. 5. Electrical properties of semiconductors: electrical conductivity, charge carriers mobility, charge carrier transport models. Thermoelectric effects. Methods for determination of electrical conductivity, methods for determination of charge carrier mobility, Kelvin probe and surface potential of dielectrics. 6. Determination of electrical properties and their temperature dependence by the Van der Pauw method for thin films of semiconductors and degenerate semiconductors. Observe and describe the differences between semiconductors and degenerate semiconductors. 7. Electrical and thermoelectric properties in thin films of semiconductors and degenerate semiconductors. Learns the determination of electrical conductivity by the 4-contact method, the determination of thermoelectric properties of thin films, determines the Seebeck coefficient. Observe and describe the differences between semiconductors and degenerate semiconductors. 8. Introduction to charge carrier determination by the "Time of flight" method, its advantages and limitations. Use of the method for the determination of charge carrier mobility in thin films of organic materials, which are characterized by low charge carrier mobility. 9. Electrical properties of polymer matrices with polar organic molecules. Use of Kelvin probe method for determination of work function of conductors and surface potential of dielectrics.   10. Presentation of laboratory works. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- | --- |
| ***Study Course Title*** | ***Computational Fluid Dynamics*** | |
|  | Physics and astronomy | |
| ***Credits*** | 2 | |
| ***Total Number of Contact Hours*** | 32 | |
| ***Number of Lecture Hours*** | 20 | |
| ***Number of Seminar and Practical Assignment Hours*** | 0 | |
| ***Number of Laboratory Work Hours*** | 12 | |
| ***Independent Study Hours*** | 48 | |
| ***Course Approval Date*** | 20.04.2021 | |
| ***Course Developer*** | Dr.phys. Leonīds Buligins; Dr.phys.Vadims Geža | |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. | |
| ***Study Course Abstract*** |  | |
| The aim of the course is to learn numerical methods of solving hydrodynamic problems  Tasks of the course are to:   1. get acquainted with the basics of numerical hydrodynamics, discretization schemes of equations, and their properties. 2. learn approaches used in CFD to solving turbulent flows 3. learn multiphase flow calculation methods 4. acquire practical skills in the applications of numerical hydrodynamic methods in the development of laboratory works.   Languages of instruction are Latvian and English. | | |
| ***Learning Outcomes*** |  | |
| Knowledge:   1. Explains the basics of finite volume method; 2. Explains discretization of transport equations; 3. Describes discretization scheme stability analysis; 4. Modelates turbulence; 5. Understands VOF algorithm for free surface flows;   Skills:   1. Formulates fluid dynamics problems mathematically; 2. Practically uses numerical modelling programs (Ansys Fluent) for simulation of fluid dynamics problems; 3. Analyzes obtained results;   Competence:   1. Critically analyses principles in modelling of fluid dynamics processes; 2. Independently formulates applicability limitations of used models; 3. Justifies choice of used models. | | |
| ***Course Plan*** | | |
| *(No.,topic, planned amount in hours)*   1. Convection-diffusion problems. L4 2. Stability analysis on numerical shemes. L4 3. Velocity-pressure coupling algorithms in flows. L4 4. SOLA-VOF algorithm for free surface flow problems. L4 5. Turbulences modeling. L4 6. Problem No.1. Laminar flow in square cavity. Ld4 7. Problem No.2. Calculation of the free surface of liquid in rotating vessel with VOF method. Ld4 8. Problem No.3. Calculation of the averaged velocities and velocity pulsations with model of turbulence and comparison with measurement. Ld4   L - lecture, S - seminar, P - practical work, Ld- laboratory work | | |
| ***Characterization of students' independent work organization and tasks*** | | |
| During this course, the student independently participates in modelling laboratory works, creating mathematical models in the offered numerical hydrodynamics modeling programs using the descriptions of the laboratory work. | | |
| ***Requirements for Awarding Credits*** | | |
| The final mark consists of:  Intermediate tests:   1. Laboratory works Nr.1 - 25%; 2. Laboratory works Nr.2 - 25%; 3. Laboratory works Nr.3 - 25%;   Final examination:   1. Exam (oral) - 25%.   All laboratory exercises have to be carried out and assessed. All exercises assessed with mark which forms the total mark for the course.  The quality and representation of the numerical results, error estimation, documentation of the numerical experiment, theoretical background, conclusions. In discussion student has to demonstrate the understanding of the problem. | | |
| ***Criteria for Evaluation Learning Outcomes*** |  | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***     |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | | 1. Laboratory work Nr. 1 | x | x | x |  |  | x | x | x | x | x | x | | 1. Laboratory work Nr. 2 |  |  |  | x |  | x | x | x | x | x | x | | 1. Laboratory work Nr. 3 |  |  | x |  | x | x | x | x | x | x | x | | 1. Exam | x | x | x | x | x |  |  |  | x | x | x | | | |
| ***Compulsory Reading List*** | | |
| 1. Anderson, J. Computational Fluid dynamics, McGraw Hill, 1995 2. Roache, P. Computational Fluid Dynamics, Hermosa Publishers, 1976 3. Versteeg, H.K., Malalasekera, W. An introduction to Computational Fluid Dynamics, Longman Scientific & Technical, 1995. | | |
| ***Further Reading List*** | | |
| 1. Halliday, D., Resnick, R., Walker, J. Fundamentals of Physics, 6th edition, John Wiley & Sons Inc., 2001 | | |
| ***Periodicals and other sources*** | | |
| 1. Reviews of Modern Physics, American Physical Society, www.rmp.aps.org (pieejams no LU IP adresēm) | | |
| ***Course Content*** |  | |
| **1. Convection-diffusion problems L4**  Transfer equation. One-dimensional problem without sources. Central difference scheme. Oriented Difference Scheme. The hybrid difference scheme. The power-law scheme. Second order schemes. QUICK scheme. Mass and heat transfer equations. Finite volume method. Boundary conditions and starting conditions.  **2. Scheme stability analysis L4**  Differences between continuous and discrete equations. The concept of numerical scheme. Stability of schemes and its analysis methods. Discrete perturbation method. An effective way to study the stability of schemes. Numerical viscosity for a circuit with oriented differences.  3. Pressure-velocity coupling algorithms L4  Offset grid concept. Differential equations for the velocity component. SIMPLE, SIMPLER, SIMPLEC and PISO algorithms, their comparison.  **4. VOF algorithm for problems with free surface L4**  Problems with a free surface, their formulation and solution. Numerical methods for solving problems with free surface. The concept of fluid volume of fluid (VOF). Donor and acceptor cells. VOF transfer equation for donor and acceptor cells.  **5. Turbulence modeling L4**  Physical quantities in turbulent flow. Coherent structures. The concept of Reynolds averaging. Instantaneous, mean and pulsation values ​​of physical quantities. Time-averaged Navier-Stokes equations for turbulent flow. The concept of turbulence models, their classification. k-turbulence model, Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES) modeling.  **6. Laboratory work No.1.**  Laminar flow in a square cavern. Ld4  Students simulate the flow of incompressible fluid in a square cavern of ​​1 x 1 m. The side edges and the lower edges of the square are fixed, the upper edge moves at a speed of 1 m/s. In the course of the work, two different convective transfer schemes at different grids and different Reynolds numbers are compared, the Re - order scheme and the second - order scheme - QUICK scheme. In the work, calculations are performed at Reynolds numbers 1, 100, 1000 and 10000. In each of these variants, calculations are performed with both mentioned schemes. From the calculation results obtain the velocity distributions u (0.5, y) and v (x, 0.5). Calculations are performed using three different grids - 10x10, 20x20 and 50x50. Compare the results and draw conclusions about the characteristics of each scheme.  **7. Laboratory work No.2.**  Calculation of the free surface of a liquid in a rotating vessel by the VOF method. Ld4  Students simulate the flow of incompressible fluid in a cylindrical vessel. An axially symmetric two-dimensional problem in a cylindrical coordinate system with a known stationary free surface shape is considered. Calculations are performed with Fluent using the VOF Free Surface model. Calculations are performed using a square area of ​​2x1 m. The obtained stationary free surface shape is compared with the analytical formula. Different starting conditions are selected and their impact on the results of simulation is assessed.  **8. Laboratory work No.3.**  Calculation of average velocity and velocity pulsations distributions with the k-turbulence model and comparison with experiment. Ld4  Students calculate the turbulent flow in a tube with the k-ε turbulence model, which is applicable to fully turbulent flows and is based on the transfer equations for the turbulent kinetic energy k and its dissipation rate ε. When performing turbulent flow calculations, students choose so-called Wall Function Approach, in which the dimensions of the cell closest to the wall are chosen so that its center is at a certain distance from the wall, or the Near-Wall Model Approach, in which hydrodynamic equations are solved up to the viscous sublayer using a fine grid wall near. The obtained mean velocity and turbulence kinetic energy distributions are compared with the measured values. | | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- | --- |
| ***Study Course Title*** | |  | | --- | | **Basics of mechanics of materials** | |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 28 |
| ***Number of Seminar and Practical Assignment Hours*** | 4 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr. Phil. Normunds Jēkabsons |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to make students aware of the response of different material classes to mechanical loads.  Tasks of the course are:   1. to introduce linear elasticity, viscoelasticity, fracture mechanics, plastic deformations and fatigue of materials; 2. to give examples for relevant classes of materials and elements of composite mechanics.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains mechanical stresses and strains, equilibrium equations in differential form and compatibility equations; 2. Explains Hookes law in tensor notation for an isotropic and anisotropic materials; 3. Explains basics of Linear Elastic Fracture Mechanics; 4. Describes thermoelastic and viscoelastic equations; 5. Describes foundations of theory of plastic deformations; 6. Names basics of mechanics of composite materials;   Skills:   1. Formulates boundary conditions for linear-elastic problem; 2. Modes thermoelastic or viscoelastic problems numerically; 3. Estimates load onset for crack propagation or for plastic yielding; 4. Applicates plasticity models to metallic materials;   Competence:   1. Applicates basic terms of solid mechanics and uses them in FEM software, for example. | |
| ***Course Plan*** | |
| 1. Introduction, Overview and history of material mechanics. L1 2. Stresses in continuum media. Stress tensor. L1 3. Deformations. Displacements and Cauchy strain tensor. L1 4. Basics of tensor analysis. Invariants of symmetrical 2nd rank tensors. L1 5. Hooke's law for isotropic and anisotropic body. L2 6. Basic equations of linear elasticity. L2 7. Boundary conditions an energetic principles in elasticity problems. L1 8. Thermodynamics of deformations, thermoelasticity. L1 9. Classical linear plane stress/strain problems with solutions. L2 10. \Bending of beams and plates. L2 11. Seminar on problem set N1. S2 12. Viscoelasticity phenomena and description. L2 13. Elasticity limit. Yielding, yield surface. Plastic deformations. L2 14. Kinetics and dynamics of yield surface. Plastic hardening models for metals. L2 15. Linear Fracture Mechanics. Griffith energy criterion for crack. Fracture toughness. L2 16. Fatigue of materials. L2 17. Composites. Fiber composites. Basic properties of constituents and composite. L2 18. Modeling of composites. L2 19. Seminar on problem set N2. S2   L – lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| During the course student will receive two sets of exercises for independent work. These sets will be evaluated on a 10-point scale. Minimum grade from both sets is 8 points. After reaching that limit student can be qualified for an exam. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. two sets of exercises as an independent work - 50%   Final examination:   1. Exam (oral) - 50%   Student qualifies for an examination only after reaching 8pt for both sets of exercises together. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | | 1. Independent works (or in groups) | + | + | + | + | + | + | + | + | + | + | + | | 1. Exam (oral) | + | + | + | + | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Fung, Y.C., Tong, P. Chien, T. Classical and Computational Solid Mechanics, Publisher: WSPC; 2 edition (May 26, 2017), ISBN-10: 9814713651 | |
| ***Further Reading List*** | |
| 1. Anderson, T.L. Fracture Mechanics: Fundamentals and Applications, Fourth Edition. CRC Press; 4 edition (February 23, 2017) 2. Helllan, K. Introduction on fracture mechanics. 3. Lavendels, E. Elastības teorija. 4. Lemaitre, J., Chaboche, J.C. Mechanics of Solid Materials, Cambridge University Press; 1 edition (September 28, 1990), ISBN-10: 0521328535 5. Suresh, S. Fatigue of Materials (Cambridge Solid State Science Series) Second Edition, Cambridge University Press; 2 edition (November 28, 1998); 6. Амензаде, Ю. Теория упругости. 7. Ландау, Л., Лифшиц, М. Теория упругости.   Работнов, Ю. Механика деформируемого твердого тела. | |
| ***Periodicals and other sources*** | |
|  | |
| ***Course Content*** |  |
|  | |

1. Introduction, Overview and history of material mechanics. Basic principles, deformations of solid body, continuum approach, application to materials
2. Stresses in continuum media. Stress vector, Cauchy stress tensor. Relation between stress vector and stress tensor.
3. Deformations. Coordinate systems and displacements in deformed and initial body configurations. Change or interval due to deformations. Strain tensor. Cauchy strain tensor.
4. Basics of tensor analysis. Coordinate transformations 2nd rank of tensors. Symmetric tensors. Eigenvalue problem for main axes. Invariants of symmetrical 2nd rank tensor. Partition of tensor in spherical and deviatoric components.
5. Hooke's law for isotropic and anisotropic body. Tensor and matrix forms. Jung's modulus, shear modulus, Poisson's ratio. Lame expressions for an isotropic body. Bulk modulus.
6. Basic equations of linear elasticity. Force balance for small body element, differential equation of force equilibrium. Compatibility. Beltrami equations.
7. Boundary conditions an energetic principles in elasticity. Lame differential equations. Elastic problem for small deformations.
8. Thermodynamics of deformations, thermoelasticity. Thermodynamical potentials. Free energy and thermodynamical forces. Thermal expansion, residual thermal strains,
9. Classical linear plane stress/strain problems with solutions. Two dimensional problems, stress or strain formulations, solutions.
10. Bending of beams and plates. Euler-Bernoulli beam theory, Kirchhoff plate theory. Solutions of simple bending problems.
11. Viscoelasticity phenomena. Creep and relaxation. Kelvin-Voight and Maxwell bodies. Combined models.
12. Elasticity limit. Yielding, yield surface in 6 DEOF stress space. Von Misses and Treska kriterions. Plastic deformations.
13. Flow Plasticity Theory. Kinetics and dynamics of yield surface. Load curves and plastic hardening models for metals. Pragers hardening rule. Armstrong-Frederick model.
14. Linear Fracture Mechanics. Griffith energy criterion for crack. Irwins modification. Fracture toughness.
15. Fatigue of materials, Micro-damage accumulation due to cyclic loads. Stress and strain approaches, S-N curves.
16. Composites. Fiber composites. Basic mechanical properties of constituents. Properties of composite and constituents. Weibull statistics for an individual fiber, strength of fiber bundle.
17. Modeling of composites. Effective fiber length in composite. Shear lag model. Models of elastic properties (direct and harmonic rules of mixtures) and micro-mechanical models for fracture.

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | ***Models of electromagnetism*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 16 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.phys, Andris Muižnieks  Dr.phys. Armands Krauze |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to give students an idea of different electromagnetic processes and mathematical models that are used to model these processes.  Tasks of the course are to:   1. become familiar with different types of electromagnetic processes which appear in various engineering problems; 2. learn approximations and equation systems that are used for  mathematical modeling of these electromagnetic processes; 3. learn how to define boundary conditions necessary to solve the electromagnetic problems in question; 4. learn how to use 2D finite element program package “FEMM” to perform numerical simulations of electromagnetic problems; 5. gain experience by performing calculations in practical work assignments with the process models discussed in the lectures and analyzing the obtained results.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Describes characteristics of different types of electromagnetic processes;   Skills:   1. Formulates mathematical models for different electromagnetic processes; 2. Carries out numerical simulations of electromagnetic processes with a specialized finite element program package;   Competence:   1. Critically analyses and evaluates different approximations used for mathematical modeling of electromagnetic processes. | |
| ***Course Plan*** | |
| 1. Direct current in conductors. L2 P2 2. Electrostatic fields, conductors. L2 P2 3. Electrostatic fields, dielectric materials. L2 P2 4. Magnetostatic fields, magnetic materials. L2 P2 5. Eddy currents. L2 P2 6. Skin-effect. L2 P2 7. High frequency electromagnetic fields. L2 P2 8. Electromagnetic waves. L2 P2   L – lecture P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students organize their independent work themselves.  Independen tasks are:   1. Study lecture conspectus of this course and related literature; 2. Solve numerically problems described in the lecture conspectus and assigned as a part of the laboratory work. Use a special finite element program package for electromagnetic field calculations for that purpose. Obtained calculations results should be presented in the form of reports (eight reports in total). | |
| ***Requirements for Awarding Credits*** | |
| The final mark consists of :  Intermediate tests:   1. 8 Practical work reports – 80%   Students carry out numerical simulations of electromagnetic processes using a specialized finite element program package as a practical work assignment (one for each lecture). They present the results of their simulations in the form of reports (eight in total).  Final examination:   1. Exam (oral) – 20%   Three control questions from the lecture conspectus are answered  Students are admitted to the final exam only after finishing all the intermediate tests. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | 1. | 2. | 3. | 4. | | 1. Intermediate tests | X | X | X | X | | 1. Exam | X |  |  | X | | |
| ***Compulsory Reading List*** | |
| 1. Jackson, J.D. Classical Electrodynamics. 3d edition. John Wiley & Sons, Inc. 2. Platacis, E. Elektrība, Rīga, 1974 3. Šilters, F., Sermons, G., Miķelsons, J. Elektrodinamika, Zvaigzne, 1985 | |
| ***Further Reading List*** | |
| 1. Grabovskis, R. Fizika, Rīga, 1983. 2. Halliday, D., Resnick, R., Walker, J. Fundamentals of Physics, 6th edition, John 3. Šilters, F. Rokasgrāmata fizikā, Rīga, 1988. 4. The Feynman lectures on physics, jebkurš izdevums Wiley & Sons Inc., 2001. | |
| ***Periodicals and other sources*** | |
| 1. How Stuff Works: www.howstuffworks.com 2. Žurnāls „Ilustrētā zinātne” 3. Žurnāls „Reviews of Modern Physics, American Physical Society”,  https://journals.aps.org/rmp/   (pieejams no LU IP adresēm). | |
| ***Course Content*** |  |
| **Lecture 1. Direct current** (lecture time two hours, practical assigned work two hours).  A mathematical model for distribution of direct electric current density in electric conductors is discussed in this lecture. An equation and boundary conditions are derived for the scalar potential of the electric field. Further, a cone-shaped conductor is considered, and an approximate analytical solution is obtained for the distribution of the electric current density in it, as well as for its resistance. Corresponding numerical simulation results are presented for two different cone angles, and the numerical results are compared with the analytical solution. Additionally, results of a numerical simulation for an axisymmetric conductor of complex shape are discussed. As a practical work, students repeat numerical simulations presented to them in the lecture and compare their results with the results from the lecture. A numerical simulation of an additional problem is assigned to students as an independent work.  **Lecture 2. Electrostatic field, conductors** (lecture time two hours, practical assigned work two hours).  In this lecture, a mathematical model for the electrostatic field in the presence of electric conductors is considered. The equation for the scalar electric field potential and corresponding boundary conditions are discussed. An analytical solution for the electric field distribution generated by a point charge near an infinite conducting plate is derived. Additionally, results of numerical simulations of electric field distribution generated by a charged sphere of finite size near a relatively large conducting disc. Numerically calculated distribution of the normal component of the electric field on the disc surface is compared with the analytical solution. Similarly, simulation results for a small disc are also presented, and significant differences between these simulation results and the analytical solution are shown.  As a practical work, students repeat numerical simulations presented to them in the lecture and compare their results with the results from the lecture. A numerical simulation of an additional problem is assigned to students as an independent work.  **Lecture 3. Electrostatic field, dielectric materials** (lecture time two hours, practical assigned work two hours).  A mathematical model for an electrostatic field in which objects with dielectric properties are inserted is presented. The equation for the distribution of the scalar potential of the electric field is given together with boundary conditions for it on dielectric material surfaces. An analytical solution for a dielectric sphere inserted in an infinite homogeneous electric field is derived. Influence of the dielectric material properties on the electric field distribution in the sphere is analyzed. The analytical solution is compared to numerically obtained simulation results for several relative permittivity values of the dielectric material. As a practical work, students repeat numerical simulations presented to them in the lecture and compare their results with the results from the lecture. A numerical simulation of an additional problem is assigned to students as an independent work.  **Lecture 4. Magnetostatics, magnetic materials** (lecture time two hours, practical assigned work two hours).  In this lecture, we consider a mathematical model for a magnetostatic field in which ferromagnetic objects are inserted. Equations for the magnetic field induction and magnetic field vector potential are derived, as well as corresponding boundary conditions on surfaces of ferromagnetic materials. Several analytical solutions are obtained for problems with magnetic circuits. Results of numerical simulations for closed magnetic circuits with several different magnetic permeability values are presented along with numerical simulation results for not fully closed circuits with different air gap widths.  The numerical simulation results are compared to the analytical solutions. As a practical work, students repeat numerical simulations presented to them in the lecture and compare their results with the results from the lecture. A numerical simulation of an additional problem is assigned to students as an independent work.  **Lecture 5. Eddy currents** (lecture time two hours, practical assigned work two hours).  In this lecture, a mathematical model for generation of eddy currents in electrically conducting bodies by an alternating current in an inductor is considered. Harmonic electromagnetic field fluctuations are assumed, and displacement current is neglected to derive an equation for the complex amplitude of magnetic field vector potential. An approximate analytical solution is obtained for a distribution of eddy currents induced in a thin conducting plate by a pair of two co-axial ring inductors. Results of corresponding numerical simulations of the magnetic field and eddy current distributions for several field frequencies are also presented and compared to the analytical solution results. As a practical work, students repeat numerical simulations presented to them in the lecture and compare their results with the results from the lecture. A numerical simulation of an additional problem is assigned to students as an independent work.  **Lecture 6**. **Skin effect** (lecture time two hours, practical assigned work two hours).  In this lecture, the mathematical model for the eddy currents is applied to model the skin effect, and a simplified formula is derived for the thickness of the skin layer. An analytical solution for distributions of magnetic field and current density in an infinitely thick conductor is obtained. Results of numerical simulations of magnetic field and induced currents in a system consisting of a ring inductor and a co-axially inserted cylindrical conductor are shown for several field frequencies. Development of the skin effect at high frequencies is shown, and the numerical simulation results are compared to the analytical solution. As a practical work, students repeat numerical simulations presented to them in the lecture and compare their results with the results from the lecture. A numerical simulation of an additional problem is assigned to students as an independent work.  **Lecture 7. High frequency magnetic field** (lecture time two hours, practical assigned work two hours).  In this lecture, a mathematical model for a magnetic field in the case of a very pronounced skin effect is presented. Approximate boundary conditions for the magnetic vector potential on the conductor surface are obtained. An analytical solution is obtained for distributions of the magnetic field and linear surface current density in a system that consists of an infinitely long current wire and a parallel electrically conducting plate. Numerically calculated magnetic field and linear surface current densities for a system with a ring inductor and an inserted cylindrical conductor are presented and compared to the analytical simulation. Also, numerical simulation results are presented for a system with a ring inductor above a conducting disc with an additional ring-shaped conductor. As a practical work, students repeat numerical simulations presented to them in the lecture and compare their results with the results from the lecture. A numerical simulation of an additional problem is assigned to students as an independent work.  **Lecture 8. Electromagnetic waves** (lecture time two hours, practical assigned work two hours).  A full mathematical model with displacement currents is considered for the electromagnetic field. Wave equations for the electric and magnetic fields are derived, and corresponding boundary conditions are described. Analytical solutions are found for an electromagnetic stationary wave in an infinitely long resonator, a stationary wave in finite volume resonator, a traveling wave in a homogeneous transmission line, and a traveling wave in a rectangular waveguide. Numerical simulations for a stationary wave solution in a parallelepiped resonator are discussed (the first four modes), and the resonance frequencies are compared to the analytical solution. As a practical work, students repeat numerical simulations presented to them in the lecture and compare their results with the results from the lecture. A numerical simulation of an additional problem is assigned to students as an independent work. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Models of multi-physical processes*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 0 |
| ***Number of Seminar and Practical Assignment Hours*** | 0 |
| ***Number of Laboratory Work Hours*** | 32 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 21.04.2021. |
| ***Course Developer*** | Dr.phys. Andris Jakovičs, Dr.phys. Vadims Geža |
| ***Prerequisite Knowledge*** | Fizi5017, Computational Fluid Dynamics  Mate5035, Methods of mathemaical physics II |
| ***Study Course Abstract*** |  |
| The aim of this course is to introduce students with the development of mathematical models for the description of complex physical processes and methods for solving the relevant problems of mathematical physics.  Tasks of the course are:   1. To learn numerical modeling tools using proposed laboratory work; 2. To get acquainted with the methods of solving problems of mathematical physics within the framework of laboratory work; 3. To analyse the results obtained in the laboratory work and draw conclusions about the applicability of the methods of mathematical physics used; 4. To develop and present 4 modeling laboratory works according to the student's choice.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains basics of electromagnetically driven flows; 2. Describes thermal radiation models; 3. Describes surface diffusion processes; 4. Explains induction heating processes; 5. Understands thermal convection; 6. Explains free surface flow calculation methods; 7. Describes particle dynamic calculation approach;   Skills:   1. Formulates mathematical models of complex physical problems; 2. Practically uses mathematical modelling programs (piem. ANSYS CFX, ANSYS Fluent) for calculation of multiphysical processes; 3. Analyzes results obtained in simulation;   Competence:   1. Critically analyzes and evaluates approaches used in modelling of multiphysical problems; 2. Critically analyzes and evaluates applicability limitations of used models; 3. Justifies choice of used models. | |
| ***Course Plan*** | |
| 1. Laboratory work No. 1. Ld8 2. Laboratory work No. 2. Ld8 3. Laboratory work No. 3. Ld8 4. Laboratory work No. 4. Ld8   Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| During the course, the student independently creates mathematical models in various mathematical modeling programs, using the descriptions of the laboratory work. | |
| ***Requirements for Awarding Credits*** | |
| Final mark consists of:  Intermediate tests:   1. Laboratory works (4) – 90%   Final examination:   1. Exam (written) - 10%.   From the offered 8 works the student has to complete and defend 4 laboratory works in mathematical modelling of complex processes. For making of the laboratory works students can use the commercial or specialised program tools as well as programs created by students themselves or publicly accessible programs. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assesment | Study outcomes | | | | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | | 1. 4 Laboratory works | X | X | X | X | X | X | X | X | X | X | X | X | X | | 1. Exam |  |  |  |  |  |  |  |  |  |  | X | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Asaro, R.J., Lubarda, V.A. Mechanics of solids and materials. - Cambridge University Press, 2006, 860 pp. 2. Chung, T.J. Computational fluid dynamics. - Cambridge University Press, 2002, 1012 pp. 3. Davidson, P.A. An introduction to magnetohydrodynamics. – Cambridge University Press, 2001, 430 pp. 4. Incropera, F.P., Dewitt, D.P. Fundamentals of heat and mass trensfer. – John Wiley&Sons, 2002, 982 pp. 5. Shyy, W., Thakur, S.S., Ouyang, H., Liu, J., Blosch, E. Computational techniques for complex transport phenomena. - Cambridge University Press, 2005, 322 pp. 6. Weiyan, T. Shallow Water Hydrodynamics. -1992, 434 pp. 7. Wilcox, D.C. Turbulence modeling for CFD. – DCW Industries, 1993, 456 pp. | |
| ***Further Reading List*** | |
| 1. Crowe, C., Sommerfeld, M., Tsuji, Y. Multiphase flows with droplets and particles. – CRC Press, London, 1998, 472 pp. 2. Fox, R.O. Computational models for turbulent reacting flows. - Cambridge University Press, 2003, 420 pp. 3. Kang, S-J. L. Sintering: Densification, Grain Growth and Microstructure. - Butterworth-Heinemann, 2005, 280 pp. 4. Kantha, L.H., Clayson, C.A. Numerical Models of Oceans and Oceanic Processes. – 2000, 940 pp. 5. Lesieur, M., Metais, O., Comte, P. Large-Eddy simulations of turbulence. - Cambridge University Press, 2005, 218 pp. 6. P.J. Roache. Computational fluid dynamics. – 1976, Albuquerque, Hermosa, 616 p. (angļu un krievu val.) | |
| ***Periodicals and other sources*** | |
|  | |
| ***Course Content*** |  |
| Course content consists of four laboratory works chosen out of eight offered topics.  1. Laboratory work Nr.1  2. Laboratory work Nr.2  3. Laboratory work Nr.3  4. Laboratory work Nr.4  Offered topics:  **Work 1. Electromagnetic field, heat and mass transfer modeling in axisymmetric system.**  Induced currents, Lorentz forces and Joule heat. Electromagnetic and thermal convection and convective heat exchange in an electrically conductive melt. Melting and crystallization of material, movement of interphases. Applications of a specialized program for problem solving.  **Work 2. Weakly conductive fluid flow in a cylindrical gap.**  Magnetic fields of induced and directly supplied currents, Joule heat and electromagnetic forces. Interaction between fields of different sources. Character of flows, their intensity and heat exchange in different conditions. Using ANSYS Emag and CFX to solve a problem.  **Work 3. Modeling of surface diffusion processes.**  Sintering of porous materials - compaction of materials and increase of mechanical strength. Decrease in surface energy. Surface diffusion and volume self-diffusion. 3D model for describing surface dynamics and topology. Using a specialized program to solve a problem.  **Work 4. Modeling of thermoclimatic conditions indoors.**  Heat, air and humidity exchange. Heat conduction, convective transfer and heat radiation. Average air flow, temperature and humidity distributions in the living space. Using CFX to solve a problem.  **Work 5. Heat exchange in a molten glass.**  Laminar thermal and electromagnetic convection. Joule heat. Flow characteristics, taking into account the temperature dependence of viscosity, electrical conductivity and thermal conductivity. Radiation heat exchange. Using CFX to solve a problem.  **Work 6. Particle tracking in turbulent flow.**  Two-parameter turbulence models and particle tracking models, turbulent dispersion. Large Eddy Simulation (LES) and Lagrangian method for calculation of particle trajectories. Forces on particles. Transfer of particles of different density and electrical conductivity from a liquid in a cylindrical area. Using FLUENT to solve a problem.  **Work 7. Steel parts induction hardening modeling.**  Induced currents, Joule heat. Heat conduction, heat transfer from the surface. Temperature dependence of material properties, nonlinear magnetic properties, changes in magnetic permeability near the Curie point. Electromagnetic and thermal simulation coupling algorithms.  **Work 8. Dynamics of electrically conductive melt phase surfaces.**  Deformation of the free surface of an conductive liquid in an electromagnetic field - meniscus formation. Surface dynamics of melt phases in the process of melting and solidification. Influence of flow in these processes. Cold crucible melting and electromagnetic crystallizer. Applications of a specialized program for problem solving. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Introduction to MHD technology*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 12 |
| ***Number of Seminar and Practical Assignment Hours*** | 12 |
| ***Number of Laboratory Work Hours*** | 8 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.phys. Imants Kaldre |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the study course is to develop students' understanding of magnetohydrodynamic phenomena and their applications.  Tasks of the study course are:   1. to get an insight into the phenomena of magnetohydrodynamics in nature; 2. to get acquainted with the most typical mathematical description of different magnetohydrodynamic cases; 3. learn to create simple numerical models in Comsol software; 4. to acquire knowledge about the applications of liquid metals in different technologies; 5. to gain experience by performing measurements and processing data.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains the concept of magnetohydrodynamics and its main phenomena in nature and technique; 2. Analyses the mathematical description of these phenomena; 3. Describes the development of magnetohydrodynamics in Latvia and in the world;   Skills:   1. Applicates basic numerical simulation with Comsol program; 2. Carries out laboratory works on the velocity measurement of liquid metal and permanent magnets; 3. Carries out approximate calculations for various physics problems;   Competence:   1. Independently creates simple numerical models with Comsol; 2. Searches and analyses literature for deeper studies of particular topics. | |
| ***Course Plan*** | |
| 1. Basics of magnetohydrodynamics. L12 2. Numerical simulation practical works. P12 3. Laboratory works. Ld8   L – lecture, P – practical work, Ld – laboratory works | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students perform independent work solving the assigned tasks.  During the course, each student chooses one of the offered numerical modeling tasks and demonstration practical work and carries out their detailed research. The work is summarized in a report and submitted.  During the course, the student independently performs the following tasks.   1. Solving tasks; 2. Numerical modeling work; 3. Practical work on the topic of MHD. | |
| ***Requirements for Awarding Credits*** | |
| The final mark consists of:  Intermediate tests:   1. Practical works – 25% 2. Laboratory works – 25%   Final exam:   1. Exam (oral) – 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | | 1. Practical works |  |  |  | + |  | + | + | + | | 1. Laboratory works |  |  | + |  | + |  |  | + | | 1. Exam | + | + | + |  |  |  |  | + | | |
| ***Compulsory Reading List*** | |
| 1. Birzvalks, J. Magnetohidrodinamika, Zinātne, 1984 2. Davidson, P.A. An Introduction to Magnetohydrodynamics, Cambridge Texts in Applied Mathematics 2001 3. Jackson, J.D. Classical electrodynamics, Willey, 1962 | |
| ***Further Reading List*** | |
| 1. Molokov, S., Moreau, R., Moffat, H.K. Magnetohydrodynamics Historical Evolution and Trends, Springer, 2007 2. Roberts, P.H. An Introduction to Magnetohydrodynamics, Longmans, 1967 | |
| ***Periodicals and other sources*** | |
| 1. Magnetohydrodynamics žurnāls, <http://mhd.sal.lv/> 2. Magnetohydrodynamics, https://en.wikipedia.org/wiki/Magnetohydrodynamics | |
| ***Course Content*** |  |
| **1. Basics of magnetohydrodynamics:**  Theoretical foundations, main equations, characteristic dimensionless quantities, plasma, and liquid metal magnetohydrodynamics (MHD). Review of the most characteristic MHD flows, flow in a channel with conductive and non-conductive walls, Hartmann flow, nature of flow in case of different dimensionless quantities. MHD applications in the metallurgical industry. MHD pumps and generators, mixers, electromagnetic treatment of materials. Manifestations of MHD in nature. Sunspots, astrophysics MHD, magnetic loops, earth's magnetic field generation.  **2. Practical works of numerical modeling:**  2.1. Development of a model for calculation of current and temperature distribution in inhomogeneous environment in stationary and non-stationary case.  2.2. Flow profile calculation for MHD flow in a channel with conductive and non-conductive walls. Comparison with analytical velocity profiles.  2.3. Numerical modeling of permanent magnets and their systems, Halbach arrangement, comparison with analytical formulas and measurements with a speedometer.  2.4. Electric and magnetic field calculations around the conductor, force calculations. Numerical modeling of inductive heating for bodies of different shapes. Skins layers for different frequencies, real and imaginary current distribution, thermal power density, forces in the molten sample.  2.5. Numerical calculations of thermoelectric current in a continuous medium, on the interface of two different centers, in a porous medium or on a crystallization front  Processing of results with data processing programs (Origin, Matlab, SciDavis). Comparison of results with theoretical relationships and experimental data.  **3. Laboratory works:**  3.1. Measurement of potential differential velocity for the movement of a conducting medium (GaInSn, solid) Measurement of flow outside a pipe with a magnetic probe (Lorentz force velocimetry). Data collection and processing (averaging, filtering, approximation).  3.2. Hartmann profile measurement in the case of conductive and non-conductive walls with a velocity probe in a stationary case averaging over time. Comparison of results with numerical and analytical solution.  3.3. Measurement of force between permanent magnets, comparison with numerical calculation results and analytical calculation. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | **Theoretical hydrodynamics** |
|  | Physics and astronomy |
| ***Credits*** | *4* |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 56 |
| ***Number of Seminar and Practical Assignment Hours*** | 8 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 15.12.2015 |
| ***Course Developer*** | Dr.habil.phys. Andrejs Cēbers |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of course is to acquire the knowledge of theoretical principles of fluid mechanics.  Tasks of the course are to:   1. Learn about conservation laws in continous media mechanics; 2. Understand models of liquids – ideal liquid, viscous fluid, fluid with internal rotations; 3. Learn solutions of particular problems of hydrodynamics: - motion of the body in an ideal fluid, Stokes flow, Hele-Shaw flow; 4. Applicate an analytical functions in hydrodynamics.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Describes models of continuous media and principles of their construction; 2. Recognizes boundaries problems in continuous media mechanics;   Skills:   1. Formulates of equations of motion of continuous media; 2. Estimates methods of solution of boundary problems of continuous media mechanics; 3. Carries out dimensional analysis of equations of motion of continuous media;   Competence:   1. Describes and understands motion of continuous media in real situations. | |
| ***Course Plan*** | |
| 1. Concept of continuous media. L4 2. Material relations in hydrodynamics of viscous fluids. L3 P1 3. Reynolds number. L3 P1 4. Circulation conservation theorem. L3 P1 5. Potential flow. L3 P1 6. Flow around moving bodies. L3 P1 7. 2D dynamics of ideal fluid. L3 P1 8. Boundary layer. L4 9. Hydrodynamics of rotating fluid. L4 10. Simple waves. L3 P1 11. Shock waves. L4 12. Nonlinear waves on the surface of heavy liquid. L3 P1 13. Hele-Shaw flow. L4 14. Hydrodynamics with spin. L4 15. Hydrodynamic stability. L4 16. Hydrodynamics of wetting. L4   L – lecture, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Student during semester must solve and submit for final exam proposed problems. He/she must get acquinted with the literature.  List of problems include:   1. Kinematics of continous media; 2. Hydrodynamics of ideal liquids; 3. Hydrodynamics of viscous fluids; 4. Waves. | |
| ***Requirements for Awarding Credits*** | |
| The final mark consists of:  Intermediate tests:   1. Intermediate test Nr.1: continuous media mechanics mathematical apparatus - 10% 2. Intermediate test Nr.2: task set solution - 30% 3. Intermediate test Nr.3: task set solution – 30%   Final examination:   1. Exam (oral) – 30%   Analysis of proposed theoretical problem and general discussion on the main parts of the course. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Intermediate exam Nr.1 | X | X |  |  |  |  | | 1. Intermediate exam Nr.2 |  |  | X | X |  |  | | 1. Intermediate exam Nr.3 |  |  |  |  | X | X | | 1. Final exam | X | X | X | X | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Betčelors, Dz. Ievads šķidruma dinamikā (krievu val) - 1973 - Mir,Maskava. 2. Blūms, E., Majorovs, M.M., Cēbers, A. Magnētiskie šķidrumi. – Rīga,Zinātne,1989 (kr.val.) 3. Landau, L.D., Lifšits, E.M. Hidrodinamika (krievu val.) - 1986 - Nauka, Maskava. 4. Sedovs, L.I. Nepārtrauktas vides mehānika.( krievu val.) - 1976 - Nauka, Maskava. 5. Šlihtings, G. Robežslāņa teorija. (krievu val.) - 1974 - Nauka,Maskava. 6. Uizems, Dz. Lineārie un nelineārie viļņi (krievu val.) - 1977 - Mir,Maskava. | |
| ***Further Reading List*** | |
| 1. Saffman, P.G., Taylor, G. The penetration of a fluid into a porous medium or Hele-Shaw cell containing a more viscous liquid//Proc.Royal Society - 1958 -v.A245 - P.312-329. 2. Sedovs, L.I. Līdzības un dimensiju metodes mehānikā.- Maskava, Nauka 1977 (kr.val.) | |
| ***Periodicals and other sources*** | |
| 1. Journal of Fluid Mechanics 2. Physical Review E. 3. Physical Review Letters. 4. Physics of Fluids. | |
| ***Course Content*** |  |
| Topic 1  **Continous media**  (2 lectures- 4 hours)   1. Continous media 2. Lagrange coordinates 3. Euler coordinates 4. Volume variation of materialelement. 5. Mass conservation. Stress tensor in continous media 6. Stress on arbitrary oriented surface element 7. III   Newton’s law in continous media mechanics 8. Equation of motion of continous media. 9. Model of ideal liquid, model of viscous liquid 10. Angular momentum conservation in continuum mechanics.   Topic 2  **Material relations in hydrodynamics of viscous fluid**  (2 lectures – 4 hours)   1. Material relations in hydrodynamics of viscous fluid. 2. Navier-Stokes equation. Shear and dilation viscosities . 3. Kinetic energy theorem. 4. Energy equation in continous media mechanics. 5. Internal energy equation. 6. Fourrier law. 7. Local equilibrium hypothesis. 8. Temperature equation. 9. Continous media equation of motion in curvlinear orthogonal coordinates (cylindrical andspherical coordinates)   Topic 3  **Reynolds number**  (2 lectures – 4 hours)   1. Reynolds number. 2. Stokes approximation 3. Flow past moving sphere 4. Stokes formula   Topic 4  **Circulation conservation theorem**  (2 lectures – 4 hours)   1. Lagraange displacement 2. Deformation of surface element in moving medium 3. Vortex tube 4. Strength of vortex tube 5. Conservation of vortex flux in the barotropic liquid 6. Circulation conservation theorem 7. Vorticity equation   Topic 5  **Potenciāl flow**  (2 lectures – 4 hours)   1. Potencial flow. 2. Motion of region with the vorticity in ideal liquid (Hill’s vortex)   Topic 6  **Potential flow past moving bodies**  (2 lectures – 4 hours)   1. Potential flow past moving bodies. 2. D’Alembert’s paradox 3. Added mass 4. Lift force and Zukowski formula.   Topic 7  **Two dimensional dynamics of ideal liquid**  (2 lectures – 4 hours)   1. Two-dimensional dynamics of ideal liquid 2. Complex potential. 3. Complex velocity. 4. Method of conform transformations in hydrodynamics of ideal liquid 5. Chaplygin-Zukowski condition and the lift force   Topic 8  **Boundary layer**  (2 lectures – 4 hours)   1. Boundary layer 2. Equation of motion of liquid in boundary layer  approximation 3. Stationaryb oundary layer on the plate 4. Self-similar solutions of boundary layer equations   Topic 9  **Hydrodynamics of rotating liquid**  (2 lectures – 4 hours)   1. Hydrodynamics of rotating liquid. 2. Flows with swirl 3. Vortex explosion, Rosby number 4. Taylor-Proudman theorem 5. Taylorš column, inertial waves in swirling flow, Kelvin relation 6. Geostrophic approximation, motion in vessel with inclined bottom 7. Rosby waves 8. Planetary waves, beta plane and  dispersion relation of planetary waves 9. Atmosphere in shallow water approximation, circulation theorem of vortex in rotating liquid 10. Cyclone and anti-cyclone   Topic 10  **Simple waves**   (2 lectures – 4 hours)   1. Simple waves 2. Simple wave in gas dynamics in 1D case 3. Polytropic gas 4. Shock wave in tube (problem of piston) 5. Non;inear waves in shallow  water approximation. Hydraulic jumps   Topic 11  **Shock waves**  (2 lectures – 4 hours)   1. Shock waves 2. Conditions on discontinuity 3. Hugoniot adiabat. Piston problem and shock wave in tube Problem of explosion   Topic 12  **Nonlinear heavy liquid free surface wave**  (2 lectures – 4 hours)   1. Nonlinear heavy liquid free surface waves 2. Korteweg-de Vries equation 3. Solitons   Topic 13  **Hele-Shaw flows**  (2 lectures – 4 hours)   1. Hele-Shaw flows. 2. Saffman-Taylor instability 3. Conform maps and Saffman-Taylor solution of free interface dynamics in the Hele-Shaw cell 4. Fluid flow in porous media   Topic 14  **Hydrodynamics with spin**  (2 lectures – 4 hours)   1. Macroscopic motion caused by internal rotation 2. Negative viscosity effect   Topic 15  **Hydrodynamic instability**  (2 lectures – 4 hours)   1. Hydrodynamic instability 2. Rayleigh equation 3. Theorem about the inflection point. Kelvin instability   Topic 16  **Hydrodynamics of wetting**  (2 lectures – 4 hours)   1. Wetting angle 2. Conditions on the moving three phase contact line | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Multiphysics modeling with open source software*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 8 |
| ***Number of Seminar and Practical Assignment Hours*** | 8 |
| ***Number of Laboratory Work Hours*** | 16 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Mg.phys. Valters Dzelme  Bc.phys. Juris Venčels |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The goal of the course is to introduce students to possibilities of numerical modeling of complex multi-physical problems using free open-source tools as an alternative to expensive commercial software. An example of a multi-physical problem is liquid metal electromagnetic levitation, in which electromagnetic field is strongly coupled to liquid metal flow and surface shape changes.  Tasks of the course are:   1. To learn to work with various open-source tools:    1. Salome (geometry and mesh generation)    2. OpenFOAM (fluid flow and thermal simulations)    3. Elmer (electromagnetics, etc.)    4. EOF-Library (efficient data exchange between OpenFOAM and Elmer)    5. ParaView (visualization of simulation results) 2. To make some changes to OpenFOAM source code to adapt it for multi-physical problem simulation 3. To simulate different multi-physical problems using the mentioned tools   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands possibilities of numerical modelling of multiphysical processes (methods, software tools);   Skills:   1. Visualizes geometry and mesh generation in Salome; 2. Models simulations using OpenFOAM, Elmer and EOF-Library; 3. Visualizes simulation results with ParaView; 4. Modifies and compilates source code; 5. Uses Linux command terminal;   Competence:   1. Models complex multiphysical problems using open-source software. | |
| ***Course Plan*** | |
| 1. Introduction to numerical modelling of multiphysical processes. L2 2. Overview of commercial and free open-source simulation tools. L2 3. Geometry and mesh generation in Salome. L1 P2 4. Modelling of fluid dynamics in OpenFOAM. Source code modification. L1 P2 5. Modelling of electromagnetics in Elmer. L1 P2 6. Coupling Elmer and OpenFOAM for multiphysics modelling. L1 P2   Individual projects:  1. Liquid metal electromagnetic levitation. Ld5  2. Choice of either Ld5:  2.1. Induction heating.  2.2. Liquid metal electromagnetic stirring.  3. Other multiphysical process (free choice). Ld6  L - lecture, S - seminar, P - practical work, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is organized individually, allowing consultations with each other and with the course instructor.  Independent work:   1. Study the course literature. 2. Complete the individual modelling projects. 3. Prepare the project reports. | |
| ***Requirements for Awarding Credits*** | |
| In addition to learning numerical modelling and theoretical aspects of multifysical processes, students do geometry and mesh generation and simple physical problem. During the course students simulate two multi-physical problems given by the instructor and one freely chosen - individual projects, that must be documented in written reports and submitted to the course instructor.  Intermediate tests:   1. Solution of practical work assignments - 10% 2. Two individual projects - 50%   Final examination:   1. Exam (oral) - 40%   Solution of freely chosen multi-physical problem (individual project) and test of overall knowledge of the course contents. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1. Solution of practical work assignments |  | + | + | + | + | + |  | | 1. Two individual projects | + | + | + | + | + | + | + | | 1. Exam | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. The OpenFOAM Foundation. OpenFOAM v6 User Guide, https://cfd.direct/openfoam/user-guide-v6/ 2. CSC – IT Center for Science, Finland. ElmerFEM documentation, https://www.csc.fi/web/elmer/documentation | |
| ***Further Reading List*** | |
| 1. Davidson, P.A. An Introduction to Magnetohydrodynamics. Cambridge University Press, 2001 2. Ferziger, J.H., Peric, M. Computational Methods for Fluid Dynamics. Springer, 2002 3. Holzmann, T. Mathematics, Numerics, Derivations and OpenFOAM. Pieejams: https://holzmann-cfd.com/en/publications/mathematics-numerics-derivations-and-openfoam | |
| ***Periodicals and other sources*** | |
|  | |
| ***Course Content*** |  |
| 1. Introduction to numerical modelling of multiphysical processes;   Description of multiphysical processes with examples. Short introduction to finite element and finite volume methods, their advantages and disadvantages.   1. Overview of commercial and free open-source simulation tools;   Overview of different simulation tools. Comparison of commercial and free open-source tools. Information on installing the software used in this course.   1. Geometry and mesh generation in Salome;   Overview of different numerical mesh types (structured, unstructured). Introduction to Salome for geometry and mesh generation. Exporting mesh from Salome to Elmer and OpenFOAM formats.  Practical work: example geometry and mesh generation.   1. Modelling of fluid dynamics in OpenFOAM. Source code modification;   OpenFOAM case structure, file contents and parameter definition. Source code description, modifications and compilation.  Practical work: simulation of simple fluid dynamics problems in OpenFOAM, adding volumetric force to momentum transport equation.   1. Modelling of electromagnetics in Elmer;   Elmer case structure, file contents and parameter definition.  Practical work: simulation of simple electromagnetics problems using Elmer.   1. Coupling Elmer and OpenFOAM for multiphysics modelling;   Description of problems related to coupling different open-source tools. Information on OpenFOAM code modifications to couple it to Elmer using EOF-Library.  Practical work: simulation of simple magnetohydrodynamics problems, using coupling between Elmer and OpenFOAM.  Individual project topics:   1. Liquid metal electromagnetic levitation. Lab5   Axially symmetric simulation of liquid metal drop levitation in high-frequency magnetic field using Elmer, OpenFOAM and EOF-Library for different system parameters (magnetic field strength, liquid metal surface tension etc). Comparison of the results to literature data.  2.1. A Induction heating.  Axially symmetric simulation of induction heating using Elmer, OpenFOAM and EOF-Library for different system parameters (magnetic field frequency, material properties of the heated object etc). Comparison of the results to literature data.  2.2. Liquid metal electromagnetic stirring.  Two-dimensional simulation of liquid metal electromagnetic stirring by rotating permanent magnets using Elmer, OpenFOAM and EOF-Library for different system parameters (magnet rotation frequency, liquid metal conductivity etc). Comparison of the results to literature data and three-dimensional simulation results.  3. Other multiphysical process (free choice).  Students simulate (after confirming with the course instructor) another multiphysical process using Elmer, OpenFOAM and EOF-Library. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Physics of polymers and composite materials*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 14 |
| ***Number of Seminar and Practical Assignment Hours*** | 12 |
| ***Number of Laboratory Work Hours*** | 6 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 18.03.2021 |
| ***Course Developer*** | Dr.sc.ing., Tatjana Glaskova-Kuzmina |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to provide students an overview about the structure, physical properties and applications of polymers and composite materials (CM). The course includes an introduction to the theoretical aspects of physics of polymers and CM, solution of tasks during practical classes, as well as laboratory works and presentations in seminars to discuss results and current research results.  Tasks of study course are:   1. to introduce the basic concepts and parameters in physics of polymers and CM; 2. to comparatively analyze the structure and physical properties of different polymers and CM; linking together students' knowledge of physics, mechanics and materials science.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. explains basic regularities of the structure and physical properties of polymers and CM 2. describes the main physical properties of polymers and CM,   Skills:   1. analyzes stress-strain and thermomechanical diagrams of different polymers and CM; 2. assesses the influence of external factors on the physical properties and ageing of different polymers and CM; 3. presents research results obtained individually and in groups, by performing laboratory works;   Competence:   1. evaluates and justify the structure and physical properties of various polymers and CM; 2. applies micromechanical models to evaluate the effective mechanical properties of polymers and CM. | |
| ***Course Plan*** | |
| 1. Introduction. Classification and applications of polymers and CM. L2 2. Manufacturing technologies and construction methods for polymers and CM. L2 3. Experimental investigation methods of structure and physical properties of polymer CM. L2 4. Manufacturing of polymer CM samples. Ld3 P2 5. Effective mechanical properties of composites. L2 P1 6. Investigation and modeling of mechanical properties of polymer CM samples. Ld3 P2 7. Discussion of results. S3 8. Thermophysical properties of polymers and CM and introduction to thermoelasticity. L2 P1 9. Exposure to environmental factors and material ageing. L2 10. Basics of creep and viscoelasticity theories. L2 11. Current research in physics of polymers and CM. S3   L - lecture, S - seminar, P - practical work, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| The course includes an introduction to the theoretical aspects of physics of polymers and CM, solution of tasks during practical classes, as well as laboratory works and presentations in seminars to discuss results and current research results. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Two laboratory works performed and defended - 40% 2. Presentation, involved in activities in seminars and practical classes - 10%   Final examination:   1. Exam (oral) - 50%   Students can only take final examination if all midterm tests have been completed.  In each of the midterm tests and final exam students should receive not less than 40% of the maximum evaluation. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | |  | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1. Laboratory works | + | + | + |  | + | + | + | | 1. Presentations, activities in seminars | + | + | + |  | + | + | + | | 1. Exam | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Guedes R. M. (ed.) Creep and Fatigue in Polymer Matrix Composites. 2nd edition. Woodhead Publishing Ltd, 2019, pieejama Dawsonera datubāzē (<https://datubazes.lanet.lv:2085/abstract/9780081026021>). 2. Kalniņš M. Polimēru fizikālā ķīmija. Zvaigzne, Rīga, 1988. 3. Utracki Leszek, A., Jamieson Alexander, M. (ed.) Polymer Physics. Wiley, 2010, pieejama Dawsonera datubāzē (https://datubazes.lanet.lv:2085/abstract/9780470600153). 4. Ward, I. M., Sweeney, J. An Introduction to the Mechanical Properties of Solid Polymers. 2nd edition. John Willey & Sons, 2004, pieejama Dawsonera datubāzē (https://datubazes.lanet.lv:2085/abstract/9780470020371). | |
| ***Further Reading List*** | |
| 1. Aniskevich K., Starkova O., Jansons J., Aniskevich A. Long-term Deformability and Aging of Polymer Matrix Composites. Nova Science Publishers Inc., 2012, NY. 2. Friedrich K., Fakirov S., Zhang Zh. Polymer Composites. Springer, 2005, pieejama Dawsonera datubāzē (<https://datubazes.lanet.lv:2085/abstract/9780387262130>). 3. Kar K. K., Rana S.K., Pandey J. K. (ed.) Handbook of Polymer Nanocomposites. Processing, Performance and Application. Springer Verlag, 2015, pieejama Dawsonera datubāzē (https://datubazes.lanet.lv:2085/abstract/9783642452291). | |
| ***Periodicals and other sources*** | |
| 1. Composites Science and Technology. Elsevier, pieejams Sciencedirect datubāzē (https://datubazes.lanet.lv:2076/journal/composites-science-and-technology). 2. Mechanics of Composite Materials. Springer US, pieejams Springer Link datubāzē (<https://datubazes.lanet.lv:5301/journal/11029>). 3. Polymers. MDPI, open access journal (https://www.mdpi.com/journal/polymers). | |
| ***Course Content*** |  |
| **1. Introduction. Classification and applications of polymers and CM.**  Molecular weight distribution and its influence on mechanical and rheological properties. Macromolecular conformations. Amorphous and crystalline polymers. Thermophysical properties and transition temperatures of polymers. Structure and properties of polymers in glassy and higly elastic state. Relaxation phenomena in polymers. Polymer mixtures and methods for their preparation. Polymer composites. Hybrid composites. Reinforced composites, composites with dispersed filler particles. Layered and sandwich composites. "Green" and recycled composites. Smart and multifunctional composites. Polymer nanocomposites.  **2. Manufacturing technologies and construction methods for polymers and CM.**  Manufacturing of polymers and methods of mixing fillers. Fiber composite manufacturing techniques (contact molding, pressing, winding, pultrusion). Additive production technologies. Composite adhesive compounds. Application of nanotechnologies in composite materials. Nanofillers and nanofibers and their properties. Interaction effects in nanocomposites. Introduction of nanoparticles into polymer matrices. Sedimentation of nanoparticles on filler and fiber surfaces. Application of ultra-thin interlayers in layered composites.  **3. Experimental investigation methods of structure and physical properties of polymer CM.**  Electron microscopy (TEM, SEM), atomic force microscopy (AFM). Spectroscopy methods (infrared and Raman spectroscopy, UV absorption and scattering). X-ray diffractometry. Methods of thermal analysis (DSC, TG, DTA, DMTA). Nondestructive control of polymers and composites. Nondestructive control methods by using ultrasound, acoustic emission, infrared thermography and electromagnetic radiation.  **4. Manufacturing of polymer CM samples.**  Physical properties of different polymer matrices and fillers and reinforcement mechanisms. Preparation of standard samples of polymer composite material by direct mixing method and silicone moulds or by cutting polymer films of various size. Preparation of samples for tensile tests.  Laboratory work: Preparation of CM standard samples.  **5. Effective mechanical properties of composites.**  Micromechanical models for a polymer matrix filled with spherical, cylindrical and platelet inclusions. Principle of equivalent homogeneity. Models with a small percentage of fillings. Polydisperse and three phase models. Models with filler content close to maximum. Evaluation of upper and lower bounds of effective elasticity moduli. Macroscopic isotropic medium. Transversely isotropic medium. Elastic properties for a macroscopic isotropic medium reinforced with fibers or filled with platelets.  Individual work: tasks for calculation of effective elastic modulus using different micromechanical models.  **6. Investigation and modeling of mechanical properties of polymer CM samples.**  Laboratory work: tensile tests of polymer CM samples. Experimentally determine mechanical properties of different polymer CM in tension by using stress-strain diagrams.  Individual work: individual and group work to analyze the results obtained. Calculate upper and lower bounds of elastic modulus of polymer CM by using Hashin-Shtrikman model and compare the results obtained with the experimental data.  **7. Discussion of the results.**  Seminar work: presentation of the results of the laboratory work and active participation during the seminar.  **8. Thermophysical properties of polymers and CM and introduction to thermoelasticity.**  Thermoelasticity of polymers and CM, state equations. Thermomechanical diagrams and their analysis. Coefficient of thermal expansion. Transition temperatures. Glass transition temperature. Thermal conductivity. Specific heat capacity. Thermophysical properties of multiphase materials.  Individual work: tasks for analysis of thermomechanical diagrams, estimation of glass transition temperature and coefficient of thermal expansion.  **9. Exposure to environmental factors and material ageing.**  Physical and chemical ageing. Thermal and hydrothermal ageing. Ultraviolet radiation induced ageing. Oxidation. Water, etc. transfer of low molecular weight substances in polymers and polymer composites. Fick diffusion equation. Anomalous sorption models. Plasticization of polymers and swelling. Accelerated ageing methods for prediction of durability of polymers and CM.  **10. Basics of creep and viscoelasticity theories.**  Deformability, creep and relaxation of polymers and CM. Free volume, physical aging. The spectrum of relaxation times. Temperature-time correlation principle. Methods of experimental investigation of relaxation processes. Modeling of viscoelastic properties of polymers and polymer CM. Bolzmann superposition principle. Influence of environmental factors on short-term and long-term deformation processes.  **11. Current research in physics of polymers and CM.**  Literature review on the physical properties of modern polymers and CM and their research methods.  Seminar work: presentation and active participation during the seminar. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Microfluidics*** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 40 |
| ***Number of Seminar and Practical Assignment Hours*** | 8 |
| ***Number of Laboratory Work Hours*** | 16 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 17.03.2021 |
| ***Course Developer*** | Dr.phys.Guntars Kitenbergs, Dr.phys. Roberts Rimša |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to introduce students to basics of microfluidics, fabrication methods and applications, as well as current topics in microfluidics from the perspective of physics and other science disciplines.  Tasks of the course are to:   1. Introduce with basics of microfluidics and its main elements; 2. Allow to understand the basic working principles of microfluidic systems; 3. Learn how to fabricate and characterize a microfluidic device; 4. Introduce various microfluidics applications; 5. Learn to choose a suitable microfluidics method to solve a certain problem.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Knows main working and fabrication principles of microfluidics, as well as interdisciplinary applications; 2. Understands reasons and motivation of microfluidics evolution, as well as current trends and perspectives;   Skills:   1. Fabricates a microfluidic device using some of the different methods; 2. Uses microfluidic devices in experiment, processes and analyses experimental results; 3. Presents microfluidics topics based on microfluidics concepts in scientific literature;   Competence:   1. Chooses a suitable microfluidics method to solve a certain problem; 2. Develops and fabricates microfluidics devices in a wise manner, taking into account physical limitations, design principles and application needs. | |
| ***Course Plan*** | |
| 1. Introduction, physics at micrometer scale. L2 2. Different microlfuidic systems. L4 3. Physics of microfluidics. L8 4. Design principles in microfluidics. L2 Ld2 5. Microfluidics fabrication methods. L8 Ld4 6. Electric and magnetic fields in microfluidics. L4 7. Flow and property measurements in small scale. L4 Ld4 8. Microfluidics applications. L8 Ld6 9. Current topics in microfluidics. S8   L - lecture, Ld - laboratory work, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| During the course students work independently on:   1. Exercises; 2. Laboratory assignments; 3. Presentations.   Exercises and laboratory assignments are executed both during class and independently. Exercise set and each lab assignment is graded on a scale from 0 to 10. Successful completion of the laboratory assignments is a prerequisite for taking part in the exam. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Exercise set - 10% 2. Written test on physics of microfluidics - 20% 3. Performance in 4 lab assignments - 40% 4. Presentation on trends in microfluidics - 10%   Final examination:   1. Exam (oral) - 20% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1. Exercise set | + |  |  |  |  |  |  | | 1. Test | + |  |  |  |  |  |  | | 1. Lab assignments |  |  | + | + | + | + | + | | 1. Presentation | + | + |  |  | + |  |  | | 1. Exam | + | + |  |  | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Kirby, B.J. Micro- and Nanoscale Fluid Mechanics, Cambridge University Press, 2010 2. Squires, T.M., Quake, S.R. Microfluidics: Fluid physics at the nanoliter scale, Rev. Mod. Phys. 77, 977 (2005). <https://doi.org/10.1103/RevModPhys.77.977> 3. Tabeling, P. Introduction to microfluidics, Oxford University Press, 2005 4. Whitesides, G. The origins and the future of microfluidics. Nature 442, 368–373 (2006). <https://doi.org/10.1038/nature05058> | |
| ***Further Reading List*** | |
| 1. Bruss, H. Lecture notes on Theoretical microfluidics 2. Stone, H.A., Stroock, A.D., Ajdari, A. Engineering flows in small device: Microfluidics Toward a Lab-on-a-Chip, Annu. Rev. Fluid Mech. 36, 381–411 (2004). <https://doi.org/10.1146/annurev.fluid.36.050802.122124> | |
| ***Periodicals and other sources*** | |
| 1. arXiv: free distribution service, open-access archive, Arxiv.org 2. Biomicrofluidics (AIP) 3. Lab on a Chip (RSC) 4. Microfluidics and Nanofluidics (Springer) 5. Nature Biotechnology 6. Physical Review Fluids (APS) | |
| ***Course Content*** |  |
| 1. Introduction, physics at micrometer scale   Course organisation, requirements and content. Miniaturisation and its capabilities.   1. Different microlfuidic systems   Paper, drop, continuous microfluidics. Typical components (pumps, chips, analytical methods) and their operating principles.   1. Physics of microfluidics   Dimensionless numbers and their use. Principles of hydrodynamics. Navier-Stokes equation in microfluidics. Poisuille flow. Diffusion, mixing. Capillarity. Surface wetting and hydrophilic/hydrophobic surfaces.   1. Design principles in microfluidics   Taking into account material characteristics in the development of microfluidic systems. Software used in development.  La: Planning of microfluidic devices.   1. Microfluidics fabrication methods   Various types of microfluidic device manufacturing – PDMS, thermoplastic materials, glass, 3D printers, paper devices. Physical limitations. Resolution. Soft lithography.  La: Fabrication of microfluidic devices   1. Electric and magnetic fields in microfluidics   Use of electrical and magnetic fields and materials in microfluidics. Electrophoresis and magnetoforesis. Properties of objects and fluids.   1. Flow and property measurements in small scale   Particle image velocimetry (PIV), particle tracking velocimetry (PTV), laser-induced fluorescence, other methods.   1. Microfluidics applications   Experiments in physics, chemistry and biology. Lab-on-a- Chip, Organ-on-a-chip  La: Practical experiments with different microfluidics applications.   1. Current topics in microfluidics S8   Student presentations on the microfluidics trends (in the form of a Journal club), presentations by microfluidic-related researchers and innovative company representatives | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | ***Soft nanomaterials*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 14 |
| ***Number of Seminar and Practical Assignment Hours*** | 2 |
| ***Number of Laboratory Work Hours*** | 16 |
| ***Independent Study Hours*** | 48 |
| ***Course approval date*** | 18.03.2021 |
| ***Course Developer*** | Dr.phys. Guntars Kitenbergs |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the study course is to establish an understanding about types of soft nanomaterials, their applications and experimental study methods.  Tasks of the course are to:   1. get acquainted with different types of soft nanomaterials, their properties and applications; 2. understand different experimental study methods of soft nanomaterials; 3. practically master experimental study methods of such materials; 4. apply experimental methods for solving open-ended problems.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:  1. Knows different types of soft nanomaterials, their properties and applications (MN2, MN8).    Skills:  2. Uses various experimental methods to determine the properties of soft nanomaterials (MN6)  3. Solves open-ended problems for which the solution is unknown (MV1);  Competence:  4. Chooses a suitable method for determining the properties of soft nanomaterials (MN6, MN7.2). | |
| ***Course Plan*** | |
| 1. Introduction. Aim and content of the course. Types of soft nanomaterials. L3  2. Properties and study methods of soft nanomaterials. L4  3. Viscoelastic media. Rheology. L2  4. Microrheology (active / passive) and its methods. L3  5. Open-ended laboratory works on soft nanomaterials. Ld16  6. Presentations of laboratory work results. S2  7. Current research on soft nanomaterials. L2  L - lecture, Ld - laboratory work, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work will involve preparation of various deliverables for assessments (described in section "Criteria for Evaluating Learning Outcomes"). In the beginning of the course students will be introduced to principles of preparing deliverables. Consultations (both remote and in person) will be available for unclear questions. | |
| ***Requirements for Awarding Credits*** | |
| Final grade consists of:  Intermediate tests:   1. Tests on course content – 30% 2. Laboratory work and presentation - 50%;   Final examination:   1. Exam (oral) - 20%. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Type of Assessment | Learning Outcomes | | | | | 1. | 2. | 3. | 4. | | 1. Tests on course contents | + |  |  |  | | 2. Laboratory works |  | + | + | + | | 3. Exam | + |  |  | + | | |
| ***Compulsory Reading List*** | |
| 1. Doi, M. Soft matter physics, Oxford University Press, Oxford, 2013 2. Furst, E.M., Squires,T.M. Microrheology, Oxford University Press, 2017 3. Mezger, T.G. The Rheology Handbook, 3rd revised edition, Vincentz, 2011 | |
| ***Further Reading List*** | |
| 1. Hassan, P.A. et al. (2015). Making Sense of Brownian Motion: Colloid Characterization by Dynamic Light Scattering. Langmuir, 31, 3–12. DOI:10.1021/la501789z 2. Piazza, R. Soft matter – the stuff that dreams are made of, Springer, 2011. | |
| ***Periodicals and other sources*** | |
| 1. Distribution service and an open-access archive for scholarly articles: arXiv.org 2. European Physical Journal E 3. Physical Review E 4. Soft Matter (Royal Society of Chemistry) | |
| ***Course Content*** |  |
| 1. **Introduction. The aim and content of the course. Types of soft nanomaterials.**   Introduction on the aim, structure and evaluations of the course. Overview of the types of soft nanomaterials. Colloids, polymers, surfactants. Methods for creation and synthesis, applications.   1. **Properties and research methods of soft nanomaterials.**   Size of nanomaterial elements and their distributions. Surface charge. Interactions. Magnetic properties. Surface tension. Methods for the determination of properties.   1. **Viscoelastic environments. Rheology.**   Viscosity and elasticity. Viscoelasticity. Examples of viscoelastic media. Rheology. Commonly used models. Rheological measurements.   1. **Microrheology (active / passive) and its methods**   Microrheology - experimental measurement methods, introducing active and passive methods, measurement interpretation, applications.   1. **Open-ended laboratory works on soft nanomaterials**   Laboratory works without a certain solution as a training task for the solution of a problem situation. The problem to be solved is chosen depending on the students' interests and technical possibilities.   1. **Presentations of laboratory works.**   Students present the results of research conducted within the laboratory works.   1. **Current research on soft nanomaterials**   Presentations on recent and current research on soft nanomaterials in Latvia and the World. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Classical mechanics*** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 40 |
| ***Number of Seminar and Practical Assignment Hours*** | 24 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.phys. Ivars Driķis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the study is to give students knowledge about the methods of analytical solution of mechanical problems.  Tasks of the study course are to:   1. introduce Newton's formalism for the description of particles, particle systems and rigid bodies; 2. acquire basic skills in using Lagrange and Hamilton formalism; 3. solve a series of example problems of different levels of difficulty.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knoowledge:   1. Describes various forms of description of the motion of point particle; 2. Explains application of Newtonian approach to motion of point particle; 3. Describes peculiarities of motion in central force field; 4. Explains theoretical aspects of the motion of system of point particles; 5. Describes theoretical aspects of the motion with constraints; 6. Names variational principles of mechanics; 7. Describes Lagrangian and Hamiltonian approach; 8. Explains description of the motion of rigid bodies and corresponding theoretical aspects; 9. Explains description of the motion in non-inertial reference frame  and corresponding theoretical aspects;   Skills:   1. Solves general motion in one dimension; 2. Solves general oscillatory problems; 3. Solves problems related to vibration of constrained system of particles; 4. Solves static problems using the principle of virtual work; 5. Solves problems using Lagrange and Hamilton equations; 6. Solves problems of the motion of rigid bodies in Euler and Lagrange cases;   Competence:   1. Chooses an appropriate mechanics model and research method for solving practical problems. | |
| ***Course Plan*** | |
| 1. Kinematics of point particle. L4 P2 2. Dynamics of point particle. L10 P8 3. Mechanics of particle systems. L12 P4 4. Variational principles of mechanics. Canonical transformations. L6 P6 5. Mechanics of rigid body. L6 P2 6. Motion in noninercial frames of reference. L2 P2   L – lecture, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students’ independent work is organized individually as well as in groups.   1. Study of literature in compulsory reading list; 2. Solving homework problems. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Written tests, topic “Point particle mechanics”  – 17 % 2. Written tests, topic “Mechanics of system of particles”  – 17 % 3. Short individual tests  – 17 % 4. Home works  – 17 %   Final examination:   1. Exam (written) – 32 % | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **Type of assessment** | **Learning outcomes** | | | | | | | | | | | | | | | | | | **1.** | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. | | 1. Test Nr.1 | + | + | + |  |  |  |  |  |  | + | + | + |  |  |  |  | | 1. Test Nr.2 |  |  |  | + | + | + | + | + |  |  |  |  | + | + | + |  | | 1. Short individual tests | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | | 1. Home works | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | | 1. Exam | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Goldstein, H. Ch. Poole, P., Safko, J. L. Classical Mechanics. Addison Wesley, 2003. 2. Greiner, W. Classical Mechanics – Systems of particles and hamiltonian dynamics, Springer, 2003 3. Landau, L. D., Lifshitz, E. M. Mechanics, Butterworth-Heinemann, 1976 | |
| ***Further Reading List*** | |
| 1. Kepe, D. Vība, J. Teorētiskā mehānika, RTU, Rīga, 1990 2. Невзглядов, В. Г.Теоретическаяа механика, Физматгиз, Москва, 1959 | |
| ***Periodicals and other sources*** | |
| 1. Reviews of Modern Physics, American Physical Society, www.rmp.aps.org (pieejams no LU IP adresēm) | |
| ***Course Content*** |  |

**Part 1. Point particle kinematics**

4 lecture hours, 2 practical work hours

**Lecture 1.** Orthogonal curvilinear coordinates. Parameters Lamé.

**Lecture 2.** Trajectory, velocity and acceleration in orthogonal curvilinear coordinates. Natural parametrization of the trajectory of the particle. Acceleration in Frenet frame.

**Practical 1.** Problem solving

**Part 2. Point particle dynamics**

***Numerical methods of statistical physics***10 lecture hours, 8 practical work hours

**Lecture 3.** Basic concepts of dynamics. Newton’s axioms. Conservation laws in point particle dynamics.

**Lecture 4.** Galilean transformation. Basic problem solving in linear motion

**Practical 2**. Problem solving

**Lecture 5**. Central fields, corresponding conservation laws. Binet equation.

**Lecture 6**. Coulomb potencial, orbital motion. Collisions and scattering.

**Practical 3**. Problem solving

**Lecture 7**. The pendelum. The harmonic oscillator with friction. The externally excited harmonic oscillator, resonanse.

**Practical 4**. Problem solving

**Practical 5. Intermediate examination**

**Part 3. Mechanics of system of particles**

12 lecture hours, 4 practical work hours

**Lecture 8**. System of free particles. Linear momentum, conservation of linear momentum. Center of gravity.

**Lecture 9**. Angular momentum, transformation of angular moment. Kinetic energy of system, König's theorem. Total energy of system.

**Lecture 10**. Constraints and constraint reactions. Classification of constraints. Virtual displacement. Degrees of freedom, independent parametrs of motion. Ideal constraints

**Lecture 11**. The principle of virtrual work in dynamics. Equation of Lagrange, type 1. The principle of virtrual work in static.

**Practical 6**. Problem solving

**Lecture 12**. Generalized coordinates. Generalized forces. Equation of Lagrange, type 2. Energy conservation in generalized coordinates.

**Practical 7**. Problem solving.

**Lecture 13**. Vibration of constrained system of particles.

**Part 4. Variational principles and canonical equations of motion**

6 lecture hours, 6 practical work hours

**Lecture 14**. Principle of least action. Equation of Lagrange as consequence of the principle of least action.

**Practical 8**. Problem solving

**Lecture 15**. Generalisation of conservation laws, Noether's theorem.

**Lecture 16**. Hamilton’s equations. Liouville's theorem. Canonical transforms.  Action function. Hamilton-Jakobi equation

**Practical 9**. Problem solving

**Practical 10. Intermediate examination**

**Part 5. Mechanics of rigid bodies**

6 lecture hours, 2 practical work hours

**Lecture 17**. Degrees of freedom of rigid bodies. Rotation about a fixed axis. Euler angles. Euler kinematic equations

**Lecture 18**. Kinetic energy of rigid bodies. Itensor of inertia. Angular momentum of rigid body. Euler dynamic equations.

**Lecture 19**. Theory of the top. Euler and Lagrange cases.

**Practical 11**. Problem solving

**Part 6. Non-inertial reference frame**

2 lecture hours, 2 practical work hours

**Lecture 20**. Newton’s equation in systems with arbitrary relative motion. Coriolis acceleration. Equation of motion in the rotating coordinate system. Inertial forces. Free fall on the rotating Earth. Foucault's pendelum.

**Practical 11**. Problem solving

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | ***Statistical thermodynamics*** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 38 |
| ***Number of Seminar and Practical Assignment Hours*** | 26 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | *20.04.2021* |
| ***Course Developer*** | Dr.habil.phys. Andrejs Cēbers |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of course is to acquire basic knowledge of thermodynamics and statistical physics.  Tasks of the course are to:  1. learn postulates and laws of thermodynamics;  2. understand entropy and Clausius inequality;  3. obtain knowledge about Jacobians and their applications;  4. learn ensembles and ergodic hypothesis;  5. learn microcanonical, canonical and big canonical ensembles;  6. obtain knowledge about Fermi and Bose statistics.  Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Names laws of thermodynamic; 2. Names methods of statistical physics;   Skills:   1. Applies thermodynamics for solution of particular problems; 2. Applies methods of statistical physics to obtain equations of state of materials; 3. Manages basics of probability theory;   Competence:   1. Analyze properties of macroscopic materials on the basis of thermodynamics and statistical physics. | |
| ***Course Plan*** | |
| *(No., topic, planned amount in hours)*  Lectures   1. Subject of thermodynamics and its postulates. L2 2. Laws of thermodynamics. L2 3. Thermodynamical temperature. L2 4. Entropy. L2 5. Thermodynamical functions. L2 6. Thermodynamical fluctuations L2 7. Multicomponent systems. L2 8. Chemical reactions. L2 9. Subject of statistical physics. L2 10. Examples of application of statistical methods. L2 11. Entropy in statistical physics. L2 12. Temperature in statistical physics. L2 13. Fluctuations in statistical physics. L2 14. Systems with variable number of particles. L2 15. Quantum statistics. L2 16. Thermodynamical properties of quantum systems. L2 17. Thermal radiation. L2 18. Oscillations in crystals. L2 19. Several problems of contemporary statistical physics. L2   Practical work   1. Jacobians and their application for calculation of thermodynamic properties. P4 2. Entropy as function of state. Its application for study of the thermodynamic properties of matter. P4 3. Thermodynamic potentials. Their application for study of thermodynamic properties. P2 4. Thermodynamics of Chemical reactions. Reaction constant. Its application for the study of content of mixtures. P2 5. Systems with variable number of particles. Cryoscopic and ebulioscopic constants and their application for the study of thermodynamic properties of matter. P2 6. Ergodic theorem for oscillator. Area of sphere in multidimensional space. P2 7. Calculation of distribution function of random walk. Mean value. Dispersion. P2 8. Binomial and Gauss distributions and their properties. Pouasson distribution. Law of big numbers. P2 9. Calculation of thermodynamic properties by canonical distribution. Multiatom gases. Matter in electromagnetic field. P2 10. Calculation of energy level distributions for different systems. P2 11. Thermodynamic properties of Bose and Fermi gases. P2   L – lectures P –practicl work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Student solves proposed list of problemes. Aquired knowledge is checked in three tests. Problems not solved during the tests should be shown on the final exam:   1. Test – I and II laws of thermodynamics. Jacobians; 2. Test – Phase transformations and chemical reactions; 3. Test – Statistical physics. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Test – 25% 2. Test – 25% 3. Test - 25%   Problems not solved during the test should be shown on the final exam.  Final examination:   1. Exam (oral) – 25%   In the final exam student shows knowledge and understanding of one theoretical problem, solve one or several problems and show problems not solved during the tests | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Test | X |  | X |  |  | X | | 1. Test | X |  | X |  |  | X | | 1. Test |  | X |  | X |  | X | | 1. Exam | X | X | X | X | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Cēbers, A. Termodinamika un statistiskā fizika. 2006. E-kurss. [URL: http://dwebct.lanet.lv/] 2. Fermi, E. Thermodynamics, Dover New York. 3. Kubo, P. Termodinamika, Mir,Maskava,1970 (kr.val.). 4. Kubo, R. Statistical Mechanics, North-Holland Publishing Company, 1990 | |
| ***Further Reading List*** | |
| 1. Kittels, Č. Statistiskā termodinamika, Nauka,Maskava,1977 2. Landau, L.D.., Lifšitcs, E.M. Statistiskā fizika, Nauka, Maskava, 1967 (kr.val.). 3. Ļeontovičs, M.A. Ievads termodinamikā. Statistiskā fizika. Nauka,1983 (kr.val.) 4. Rolovs, B. Termodinamika un statistiskā fizika. Zvaigzne, Rīga, 1967. 5. Zommerfelds, A. Termodinamika un statistiskā fizika, Maskava, 2002 (kr.val.) | |
| ***Periodicals and other sources*** | |
| 1. American Journal of Physics 2. Los Almos Natuional Laboratory. xxx.lanl.gov 3. Physical Review E, Physical Review Letters | |
| ***Course Content*** |  |
| Topic 1  **Laws and postulates of thermodynamics**  (2 lectures – 4 hours)   1. Postulates of thermodynamics. 2. I and II laws of thermodynamics. Kelvin and Clausius formulations of II law of thermodynamics and their equivalence   Topic 2  **Entropy**  (3 lectures – 6 hours)   1. Entropy. Carno cycle and thermodynamical temperature 2. Entropy of ideal gas. Sackur-Tetrode formula. 3. Planck theorem. Entropy of mixing. Gibbs paradox.. 4. Entropy and information   Topic 3  **Thermodynamical functions**  ( 2 lectures – 4 hours)   1. Thermodynamical functions 2. Free energy and its properties 3. Osmotic pressure 4. Thermodynamical theory of fluctuations and conditions of thermodynamic stability   Topic 4  **Practical work in thermodynamics**  (2 hours)   1. Jacobians. Their application to calculate the thermodynamic properties of media. 2. Entropy as function of system’s state. Its application in study of thermodynamic properties of media. 3. Thermodynamic potentials. Their application for the study of thermodynamic properties of systems   Topic 5  **Thermodynamics of multicomponent systems**  (2 lectures – 4 hours)   1. Thermodynamic theory of phase equilibria. Chemical potential 2. Gibbs potential and its properties. Clapeyron-Clausius formula, 3. Thermodynamics of multi component systems. Thermodynamics of diluted solutions.   Topic 6  **Chemical thermodynamics**  (2 lectures – 4 hours)   1. Variation of boiling and melting temperatures of diluted solutions 2. Gibbs phase rule 3. Thermodynamics of chemical reactions. Chemical reactions in gases. 4. Chemical reactions in solutions. Notion of pH.   Topic 7  **Practical work in thermodynamics**  (2 hours)   1. Thermodynamics of chemical reactions. Reaction constant. Its application for the determination content in reacting components. 2. Systems with variable number of particles. Cryoscopic and embullioscopic constants and their application to determine properties of media.   Topic 8  **Postulates of statistical physics**  ( 2 lectures – 4 hours)   1. Basics of statistical physics. Phase space. Volume in phase space. 2. Ergodic theorem. Adiabatic invariants   Topic 9  **Basics of propability theory**  ( 2 lectures – 4 hours)   1. Some simple distributions. Randomwalk. Elementary theory of Brownian motion. Statistics of polymer chains. II law of thermodynamics in fluctuating systems.   Topic 10  **Ensembles**  (4 lectures– 8 hours)   1. Microcanonical ensemble. Entropy in microcanonical ensemble 2. Sackur-Tetrode formula 3. Temperature in statistical physics 4. Canonical distribution. Statistical sum and free energy   Topic 11  **Canonical and grand canonical ensembles**  (4 lectures – 8 hours)   1. Eqvipartition principle. 2. Entropy in microcanonical and canonical ensembles and their relation 3. Grand canonical ensemble. Grand statistical sum and Ω potencial.. 4. Fluctuations in grand canonical ensemble   Topic 12  **Practical work in statistical physics**  (2 hours)   1. Ergodic theorem for oscillator. Area of sphere in multidimensional space.. 2. Distribution function calculation of random walk.Mean value. Dispersion. 3. Binomial and gaussian distributions and their properties. Poisson distribution. Law of large numbers. 4. Calculation of the thermodynamic properties of systems using canonical distribution. Gases of molecular compounds. Matter in eletromagnetic field.   Topic 13  **Quantum statistics**  ( 3 lectures – 6 hours)   1. Bose and Fermi statistics. 2. Calculation of the number of energetical states 3. Thermodynamical properties of Bose and Fermi gases 4. Heat capacity of electron gas.   Topic 14  **Applications of quantum statics**  (2 lectures - 4 hours)   1. Paramagnetic susceptibility of electron gasElektronu gāzes paramagnētiskā uzņēmība. 2. Thermal radiation. Planck formula. Induced radiation. 3. Heat capacity of crystalline lattices   Topic 15  **Practical wotk in quantum statistics**  (2 hours)   1. Calculation of number of energetical states for different systems 2. Thermodynamic properties of Bose and Fermi gases | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | **Electrodynamics** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 38 |
| ***Number of Seminar and Practical Assignment Hours*** | 26 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 23.02.2021 |
| ***Course Developer*** | Dr.phys. Sandris Lācis Dr.habil.phys. Edvīns Šilters |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of this study course is to present the theory of a electromagnetic field based on Maxwell's equations to students of physics master program, as well as to introduce students with special theory of relativity, broaden understanding of the relationship between electric and magnetic fields.  Tasks of the course are:   1. To derive Maxwell equations and acquire skills in using differential operators to describe physical fields; 2. To demonstrate the application of Maxwell's equations in the description of an electrostatics, a stationary magnetic field, electromagnetic waves and a radiation; 3. To acquire basic concepts of spacetime in the context of a special theory of relativity; 4. To acquire skills in solving problems of the classical electrodynamics.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:  1. Explains the theoretical foundations of electromagnetism, deriving them from first principles;  2. Explains the basics of Special Theory of Relativity (further STR), deriving them from first principles;  3. Understands description of scalar and vector fields and uses the Hamiltonian operator nabla.  Skills:  4. Calculates the most typical problems of vector field, electromagnetism and STR;  5. Analyses the demonstrations of electromagnetic interaction in different fields of physics;  6. Transforms electromagnetic relations by performing transitions between point and continuous distribution of electric charges, line and volumetric distribution of electric currents;  7. Applies 4D space transformations to explain the events from different reference systems and accounting for STR effects.  Competence:  8. Formulates equations and boundary conditions describing the specific manifestations of electromagnetism;  9. Chooses methods for solving electromagnetism problems;  10. Explains the manifestations of the electromagnetic field created by moving objects using SRT;  11. Is aware of ethical behaviour in the daily study process. | |
| ***Course Plan*** | |
| 1. Introduction to electromagnetism. L2  2. Scalar fields and vector fields in three-dimensional space. L2, P4  3. Electrostatic field in vacuum. L2, P2  4. Stationary magnetic field in a vacuum. L2, P2  5. Multipole expressions. L2, P2  6. Basic equations of electromagnetic field in vacuum. L3, P1  7. Conservation laws in electromagnetism. L3, P1  8. Electromagnetic waves. L2, P2  9. Electromagnetic radiation. L3, P1  10. Equations of macroscopic electromagnetic field. L2, P2  11. Introduction to Special Theory of Relativity (STR). L2, P2  12. Four-space geometry. Relativistic kinematics. L2, P2  13. Relativistic dynamics. L3, P1  14. Basic equations of relativistic electrodynamics. L2, P1  15. Charge movement in the electromagnetic field. L3, P1  16. Review of electromagnetism theory L3, P1  L – lecture, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Student independently:  1. in addition to lectures gets acquainted with the presentation of theory in course materials and textbooks;  2. solves and submits homeworks;  3. prepares for tests and exam, using the description of test topics and examples from previous years. | |
| ***Requirements for Awarding Credits*** | |
| During the semester student has to regularly submit his homework and pass 2 written tests (one on Maxwell's electrodynamics, the other on the special theory of relativity). The final written examination should be taken during the session. Attendance at lectures is not mandatory, but homework must be submitted on time, just as tests must be written at the fixed dates.  Intermediate tests:   1. Homework – 40% 2. Written test Nr.1 – 10% 3. Written test Nr.2 – 10%   Final examination:   1. Exam (written) – 40%.   If the sum of weighted marks for homework and tests is below 35%, then the student is not admitted to the exam. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | | 1. Homework |  |  | X | X | X |  | X | X | X | X | X | | 1. Written test Nr.1 | X |  | X | X |  | X |  |  |  |  | X | | 1. Written test Nr. 2 |  | X |  | X |  |  | X |  |  |  | X | | 1. Final exam | X | X |  |  | X | X |  | X | X | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Jackson, J.D. Classical Electrodynamics Third Edition, Wiley, 1998, LUB 12 eks. 2. Nolting, W. Theoretical Physics 3: Electrodynamics, Springer, 2016 3. Nolting, W. Theoretical Physics 4: Special Theory of Relativity, Springer, 2017 | |
| ***Further Reading List*** | |
| 1. Carozzi, T., Eriksson, A., Lundborg, B., Thidé, B., Waldenvik, M. Classical Electrodynamics: On-Line Exercises Book, http://www.plasma.uu.se/CED/Exercises/EMFT\_Exercises.pdf 2. Šilters, E., Sermons, G., Miķelsons, J. Elektrodinamika, Zvaigzne, Rīga, 1986Lifshitz, E. M., Landau, L. D. The Classical Theory of Fields, Fourth Edition: Volume 2, Butterworth-Heinemann, 1980 3. Thidé, B. On-Line Textbook "Electromagnetic Field Theory", Second edition, <http://www.plasma.uu.se/CED/Book/EMFT_Book.pdf> | |
| ***Periodicals and other sources*** | |
| 1. Classical Electromagnetism, http://farside.ph.utexas.edu/teaching/em/em.html 2. Electricity and Magnetism, <http://hyperphysics.phy-astr.gsu.edu/hbase/emcon.html> 3. Electromagnetism, http://en.wikipedia.org/wiki/Electrodynamics 4. MIT 8.02 Electricity and Magnetism, http://web.mit.edu/8.02t/www/802TEAL3D/ | |
| ***Course Content*** |  |
| **1. Introduction to electromagnetism L2**  History of electromagnetism. Fundamental interactions in nature and electromagnetic interactions as one of them. Units of measurement systems in electromagnetism - absolute and SI.  **2. Scalar fields and vector fields in three-dimensional space L2, P4**  Vector geometric and algebraic representations, vector operations, scalar and vector fields. Hamilton operator nabla and its application in gradient, divergence and curl calculations. Vector field integral theorems.  **3. Electrostatic field in vacuum L2, P2**  Electric charge distributions, Coulomb's law, Gauss’s law, electrostatic field curl, electrostatic field scalar potential, equation for potential. Electrostatic field energy.  **4. Stationary magnetic field in a vacuum L2, P2**  Stationary currents: volume current, linear current, discrete charge motion. Biot-Savart law. The force of current interaction. Amper's law. Vector potential, its equations.  **5. Multipole expressions L2, P2**  Multipole expressions for an electrostatic field created by localised electric charges. Moments of electric charges’ system. Elektric field of specific moment (dipole and quadrupole moment fields). Multipole expressions for magnetic field, magnetic dipole moment and its field. Force and torque acting on the dipole in an electric field.  **6. Basic equations of electromagnetic field in vacuum L3, P1**  Equations of electrostatic and stationary magnetic field, their extension to a general non-stationary case. Maxwell's differential and integral equations. Conservation of electric charge. Electromagnetic field potentials. Lorenz gauge and Coulomb gauge. Electromagnetic field classification.  **7. Conservation laws in electromagnetism L3, P1**  Current continuity equation. Electromagnetic field energy density and energy flux density, Poitering equation. Use of Maxwell stress tensor in calculations of electromagnetic forces.  **8. Electromagnetic waves L2 P2**  Complex form representation of electromagnetic field with harmonic time dependence. Electromagnetic wave equations. Monochrome plane wave. Mutual alignment of electromagnetic wave vectors E, B, k. Linear, circular and elliptic polarization of electromagnetic waves. Energy carried by electromagnetic waves.  **9. Electromagnetic radiation L3, P1**  Fourier representation of electromagnetic field source densities. Radiation zones and approximations used in them. Retarded potentials of electromagnetic field. Electric dipole fields and radiation.  **10. Equations of macroscopic electromagnetic field L2, P2**  Sources of electromagnetic fields in matter: microcharges and microcurrents. Polarization and magnetization of matter, their relation to field source functions. Derivation of macroscopic Maxwell equations. Four vectors that describe macroscopic electromagnetic field and material relations. Integral equations of electromagnetic field and boundary conditions.  **11. Introduction to Special Theory of Relativity (STR) L2, P2**  STR postulates - Galileo-Einstein principle of relativity, universal limiting speed for propagation of interactions. Distance and time measurement in the reference system, time measurement synchronization. Derivation of Lorentz transformations. Time dilatation, length contraction, addition of velocities in 3D.   1. **Four-space geometry. Relativistic kinematics L2, P2**   Event space, four-radius vector (x0 and x4 representations). Lorentz transformation matrix in four-space. Relativistic interval, its classification and differential. Simultaneity of events, its relativity, proper time and distance between events. Absolute past and future, light cone. Geometric interpretation of Lorentz transformations. Four-velocity and four-acceleration vectors.  **13. Relativistic dynamics** **L3, P1**  Relativistic Lagrangian of a free particle and relativistic momentum. Relativistic mass, rest mass, full energy, rest energy, kinetic energy. Hamiltonian of a free particle. Energy-momentum four-vector, energy-momentum conservation law. Newton second law in STR.  **14. Basic equations of relativistic electrodynamics L2, P1**  Electromagnetic field four-potential and four-current. Equations for electromagnetic field potential in STR. Lorentz transformations of four-potential and four-current. Electromagnetic field tensor, Maxwell's equations in STR. Lorentz transformations for electromagnetic field. Four-wave vector, electromagnetic waves and relativistic Doppler effect.  **15. Charge movement in the electromagnetic field L3, P1**  Lagrangian for an electric charge in an electromagnetic field. Charge momentum, energy and Hamiltonian in the electromagnetic field. The equations of motion of a charged particle. Lorentz force density. Energy-momentum tensor of the electromagnetic field.  **16. Review of electromagnetism theory L3, P1**  Review of the classical theory of electromagnetism and the special theory of relativity | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | **Quantum Mechanics** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 32 |
| ***Number of Seminar and Practical Assignment Hours*** | 32 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 17.03.2021 |
| ***Course Developer*** | Dr.phys. Vjačeslavs Kaščejevs |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the study course is to provide students with understanding of fundamental principles of quantum mechanics and develop skills in applying the relevant mathematical formalism to practical problems.  Tasks of the course are:   1. To introduce basic concepts of mathematical description of quantum phenomena: state vector, operators, Born’s Law, Schrödinger’s time evolution, quantum entanglement; 2. To develop intuition about behavior of elementary quantum systems by using numerical simulations and quantum computers; 3. To acquire ability to formulate mathematical equations for specific quantum mechanical problems and choose appropriate analytical and numerical methods to solve them; 4. To learn the connections between the mathematical framework of quantum mechanics and concepts, models and approximations of other branches of physics; 5. To get acquainted with usages of theoretical relationships of Quantum Mechanics in explaining structure of matter, microscopic phenomena and development of quantum technologies.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Demonstrates deep understanding of fundamental principles and concepts of Quantum mechanics; 2. Explains phenomena in atomic, solid state and particle physics using concepts of quantum mechanics;   Skills:   1. Formulates appropriate mathematical model for quantitative description of model quantum systems; 2. Uses appropriate analytic and numerical mathematical methods for quantum mechanical problems; 3. Recognizes elements and mathematical structures of quantum theories in current scientific publications;   Competence:   1. Understands fundamental principles and current development of quantum technologies; 2. Evaluates the needs for quantum mechanical modelling in current research problems. | |
| ***Course Plan*** | |
| 1. An introductory overview of the history of quantum theory and today's role in physics and quantum technologies. L2 2. Linear algebra in Dirac notation. L4 P4 3. Conceptual framework and postulates of quantum mechanics. L2 4. Two-level system kinetics: spin one-half and qubits.  L2 P4 5. Quantum dynamics, the Shringinger equation and energy eigenstates. L2 P2 6. Two-level system dynamics.  L2 P4 7. Continuum-variable quantum mechanics, Schroedinger's wave equation. . L4 P2 8. Quantum harmonic oscillator,  creation and annihilation operators, Fock and coherent states. L2 P2 9. Perturbation theory in quantum mechanics. L2 P2 10. Quantum entanglement, non-locality, Bell inequalities. L4 P2 11. Elements of group theory in quantum mechanics. Translation, rotation and Clifford groups, symmetry of the exchange. L2 P2 12. 3D rotation, angular momentum and spherical harmonics. L2 P2 13. Hydrogen atom, L2 P2 14. Seminar on applications of quantum mechanics in current research. S4   L – lecture, P – practical work, S – seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students’ independent work is organized individually as well as in groups.   1. Individual study using textbooks and online resources; 2. Individually solving exercises in preparation for practical work; 3. Solving exercises during practical session individually, in groups with guidance; 4. Study of scientific literature, choice of seminar topic; 5. Preparation of seminar presentation. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Two tests during the semester – 40% 2. Seminar presentation – 20%   Final examination:   1. Exam (oral) – 40%.   Examination on a theory question selected during the examination and a practical problem. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1. Two tests semester | X |  | X | X |  |  |  | | 1. Seminar |  |  |  |  | X | X |  | | 1. Final exam | X | X |  | X |  | X | X | | |
| ***Compulsory Reading List*** | |
| 1. McIntyre, D. Quantum Mechanics (Pearson, 2012) 2. Nielsen, M. A., Chuang, I. L. Quantum Computation and Quantum Information(Cambridge University Press, 2010) 3. Sakurai, J.J., Napolitano, J. Modern Quantum Mechanics (Cambridge Unviersity Press, 2017) | |
| ***Further Reading List*** | |
| 1. Landau L.D., Lifšics J.M. Kvantu mehānika. Nerelatīvistiskā teorija. M.: Nauka, 1989 (krievu val.) 2. Miķelsons J., Rolovs B., Šilters E. Kvantu mehānika. Rīga: 1970. 3. Susskind, L., Friedman, A. Quantum Mechanics: The Theoretical Minimum (Basic Books, 2015). | |
| ***Periodicals and other sources*** | |
| Scientific journals and physics news portals:   1. Nature News; 2. Nature; 3. Physical Review Focus. 4. Science; | |
| ***Course Content*** |  |
| 1. Basic notions and conceptual framework of Quantum Mechanics.    * 1. History and current role of quantum theory in physics and technology.      2. Examples: De Broglie waves of a photon or an electron; spin qubits. 2. Linear Algebra in Dirac notation.    1. Axioms of Hilbert space. Inner product, norm, basis.    2. Matrix representation.    3. Self-adjoint linear operators, spectral theorem. 3. Postulates of Quantum Mechanics. 4. System and environment. Initialization, free evolution, measurement. Observables and their compatibility. 5. Representation of states and observables in Hilbert space. Born’s Law. 6. Uncertainty principle, superposition principle. 7. Two level system kinematics. 8. Spin one-half and qubit projection operators. Algebra of Pauli matrices. 9. Bloch Sphere representation. 10. Quantum dynamics. 11. Schroedinger equation in general form. Hamiltonian. Free and time-dependent quantum dynamics, special role of energy eigenstates. 12. General solution for the stationary case. Stationary Schroedinger equation as eigenvalue problem. 13. Two-level system dynamics, free rotation. Rabi oscillations. 14. Single qubit logical operations and their realization in spin systems. 15. Continuous-variable quantum mechanics. 16. Hilbert space of wave-functions. Delta function and Dirac’s improper vectors. Coordinate and momentum representations. 17. Non-relativistic single-particle Schroedinger wave equation. 18. Physical examples: electron in external field, optical quadratures of an electromagnetic field mode.. 19. Quantum harmonic oscillator, creation and annihilation operator method. Fock and coherent states. 20. Perturbation theory. 21. Perturbative diagonalization of a sum of two non-commuting operators: the case of non-degenerate eigenvalues. 22. Degenerate perturbation theory.   8. Quantum entanglement and quantum computing.   1. Two-qubit system example. Entanglement definition and its measures. 2. Nonlocality in quantum mechanics, Bell inequalities. 3. Universal local logical operation model of quantum computing. 4. Group theory elements. 5. Groups as description of physical symmetry, elements of group and Hamiltonian commutation condition. 6. Translation, rotation and Clifford groups. Examples of quantum numbers defined by group invariants: momentum, quasi-momentum, angular momentum. 7. Exchange symmetry. Boson, fermion, and anyon symmetry. 8. Spherically symmetry in quantum mechanics 9. 3D rotation group representations, angular momentum operator algebra. 10. Spherical harmonics. 11. Single-particle Keplerian motion: hydrogen atom orbitals. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Introduction in biological physics*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 26 |
| ***Number of Seminar and Practical Assignment Hours*** | 6 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.habil.phys. Andrejs Cēbers |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of course is to introduce in the subject of biological physics.  Tasks of the course are to:   1. learn elastic rod as model of biopolymers; 2. learn fluctuation-dissipation theorem and its applications; 3. learn a theoretical description on membrane; 4. introduce phase equilibrium in polymer solutions. Flory-Higgins model; 5. learn motility of microorganisms; 6. acquire abilities to use Matlab for the solution of particular problems of biological physics.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains basic physics problems in the living world; 2. Explains fluctuation-dissipation theorem to describe the phenomena in the living world;   Skills:   1. Solves in the MatLab environment the deformations of biopolymers; 2. Applicates microrheology; 3. Analyses the motion of microorganisms;   Competence:   1. Critically analyses and evaluates physical problems in the living world. | |
| ***Course Plan*** | |
| 1. Fluctuation-dissipation theorem in microrheology. Cramers-Kronig relations. L2 2. Determination of elastic modulus by passive method. L2 3. Examples: Brownian particle in viscous medium, Brownian particle in the optical field of laser tweezer. L2 4. Elastic rod model. L2 5. Equilibrium configurations of elastic rod. Euler instability. L1 P1 6. Elasticity of networks of semiflexible filaments. Brownian motion in the network of semiflexible filaments. Subdiffusion. L2 7. Macroscopic models of viscoelastic media. Maxwell model, Voigt model, Kelvin-Voigt model. L1 P1 8. Magnetic microrheology. L1 P1 9. Twist in biopolymers. Elastic rod with twist. Plectonemes. L1 P1 10. Linking number, twist and Wr. L2 11. Introduction in differential geometry of surfaces. L2 12. Gaussian curvature. Geodesics. Gauss-Bonet theorem. Euler formula. Geometric properties of fullerenes. L1 P1 13. Lipids, Membranes. Bending energy of membranes. L2 14. Thermal fluctuations of membranes. Evans experiment. Magnetic vesicules. L1 P1 15. Entropic repulsion of membranes. Laser tweezers in physics of membranes. L2 16. Molecular motors. Experimental measurement of their properties. L2   L – lecture, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students independently solve proposed list of problems. Solutions has to be handed in at final exam.  Topics:   1. Equilibrium configurations of elastic rod. Euler instability; 2. Fluctuation of elastic rod; 3. Microrheology and fluctuation-dissipation theorem; 4. DNS twist and its’ topological description. | |
| ***Requirements for Awarding Credits*** | |
| Students solve proposed list of problems, necessary basic knowledge for that is given in the lectures. During all semester the professor is available for consultations.  Intermediate tests:   1. Discussion of solutions of proposed list of problems - 80%   Final examination:   1. Presentation and analysis on the solutions of proposed list of problems - 20% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Intermediate test | x | x | x | x | x | x | | 1. Exam | x | x | x | x | x | x | | |
| ***Compulsory Reading List*** | |
| 1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., Walter, P. 2002. Molecular biology of the cell, 4th ed. New York, Garland Publishing. 2. Nelson, Ph. Biological physics. W.H.Freeman&, 2004. 3. Seifert, U. Advances in Physics, v.46,P.13-190,1997. 4. Statistical mechanics of membranes and surfaces. Vol.5 . Proceedings of the Jerusalem Winter School for Theoretical Physics, Singapore, World Scientific 1989 (eds.:D.Nelson,T.Piran, and S.Weinberg) 5. Strick, T.R. et al. Stretching of macromolecules and proteins. Rep.Prog.Phys. ,2003, v.66 ,P.1-45. | |
| ***Further Reading List*** | |
| 1. Berg, H. Motile behaviour of bacteria. Physics Today - January 2000 - P.20-29. 2. Carmo, D.M. Differential geometry of curves and surfaces, Prentice Hall, 1976. 3. Cebers, A. Dynamics of a chain of magnetic particles connected with elastic linkers. Journal of Physics: Condensed Matter – 2003, v.15 – P.S1335–S1344 | |
| ***Periodicals and other sources*** | |
| 1. Los Almos National Laboratory, xxx.lanl.gov 2. Nature, Science 3. Physical Review E,Physical Review Letters | |
| ***Course Content*** |  |
| Topic 1  **Models of biopolymers**  (lecture – 2 hours)  1. Equilibrium configurations of elastic rod. Euler instability  2. Algorithm of calculation of equilibrium configurations  Topic 2  **Thermal fluctuations  of biopolymers**  (lecture – 2 hours)  1. Persistence length  2. Cytoskeleton elasticity  3. Brownian motion in ensemble of fluctuating strings  Topic 3  **Fluctuation-dissipation theorem**  (2 lectures 4 hours)  1. Fluctuation-dissipation theorem in microrheology  2. Kramers-Kronig relation  3. Brownian particle in viscous fluid. Brownian particle in laser tweezer  4. Elastic modulus measurement by passive method\  Topic 4  **Viscoelasticity**  (lecture – 2 hours)  1. Models of viscoelastic media. Maxwell model, Kelvin model, Voigt model  2. Magnetic microreology  Topic 5  **Twist and topology of DNA**  (lecture – 2 hours)  1. Elastic rod with twist. Plectonemes.  2. Linking number, twist and writhe Wr,  Topic 6  **Membranes**  (4 lectures – 8 hours)  1. Differential geometry of surfaces  2. Gaussian curvature, geodesics, Gauss-Bonnet theorem, Euler formula  3. Lipids, their bilayers. Bending energy of membrane  4. Thermal fluctuations of membranes. Evans experiment.  5. Entropic force in membrane  Topic 7  **Molecular motors**  **(**lecture – 2 hours**)**  1. Models of molecular motors.  2. Measurement of molecular motors characteristics  Topic 8  **Electrostatics of living systems**  (2 lectures – 4 hours)  1. Electrolytes. Debay length,  2. Electrophoresis, electroosmosis  3. Electrostatic interactions in electrolyte  solutions  Topic 9  **Practical work**  ( 3 lectures – 6 hours)  1. Biological physics problems solution | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Numerical methods of statistical physics*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 14 |
| ***Number of Seminar and Practical Assignment Hours*** | 18 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.phys. Ivars Driķis |
| ***Prerequisite Knowledge*** | Fizi5014, Classical mechanics |
| ***Study Course Abstract*** |  |
| The aim of the study course is to introduce basic knowledge of modern numerical methods of statistical physics.  Tasks of the study course are to:   1. get acquainted with Monte-Carlo and numerical methods of molecular dynamics; 2. get experience in numerical modeling of Ising model; 3. get experience in numerical modeling of Einstein's crystal and numerical thermometer algorithms; 4. get experience in numerical determining of the chemical potential.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains aspects of the Metropolis algorithm of Monte Carlo method; 2. Explains theoretical aspects of the Einstein solid model; 3. Explains theoretical aspects of the Ising model;   Skills:   1. Performs numerical experiments in statistical physics;   Competence:   1. Independently selects suitable parameters for numerical experiments in statistical physics and analyzes results. | |
| ***Course Plan*** | |
| 1. Introduction. Molecular simulation. L2  2. Magnetic systems. The Ising model. L4 S6  3. From microscopic to macroscopic. L4 S6  4. The chemical potential and phase equilibria. L4 S6  L – lecture, S – seminars | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students’ independent work is organized individually as well as in groups.  Tasks:  1. Study of literature in compulsory reading list;  2. Preparation for following seminair. | |
| ***Requirements for Awarding Credits*** | |
| The final mark consists of:  Intermediate tests:   1. Presentation of the results practical work on topic “ Magnetic systems. The Ising model” on seminar – 25% 2. Presentation of the results practical work on topic “From microscopic to macroscopic” on seminar – 25% 3. Presentation of the results practical work on topic “The chemical potential and phase equilibria” on seminar – 25%   Final examination:   1. Exam (written) – 25 %   For final examination all intermediate tests have to be done. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | 1. | 2. | 3. | 4. | 5. | | 1. Test Nr.1 | X |  |  | X | X | | 1. Test Nr.2 |  | X |  | X | X | | 1. Test Nr.3 |  |  | X | X | X | | 1. Exam | X | X | X | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Gould, H., Tobochnik, J. *Thermal and Statistical Physics*,  Princeton University Press, 2010. 2. Haile, J. M. *Molecular dynamics simulations. Elementary methods*. John Wiley & Sons, New York 1992. | |
| ***Further Reading List*** | |
| 1. Allen, M. P., Tildesley, D. J. *Computer simulations of liquids*, Clarendon Press, Oxford, 1987 2. Frankel, D., Smit, B. *Understanding molecular simulations*. Acdemic Press, London, 2002 3. Hoover, Wm. G. *Molecular dynamics, In Lecture Notes in Physics, 258*. Spinger-Verlag, Brelin, 1986 | |
| ***Periodicals and other sources*** | |
| 1. Flyvbjerg, H., Petersen, H.G. Error estimates on averages of correlated data. J. Chem. Phys. , vol. 91 (1989). | |
| ***Course Content*** |  |
| 1. **Introduction. Molecular simulation.**   Thermodynamic system and thermodynamic parameters, numerical methods of statistical physics. Monte Carlo method, Metropolis algorithm. Classical dipole in an external electric field as an example of a method.   * + - 1. **Magnetic systems. The Ising model**   The Ising model as simplest model of magnetic system. Metropolis algorithm for Ising system. The Ising chain, theoretical expressions for thermodynamic parameters. Practical:  Numerical simulations of  Ising chain, 2D Ising model, ferromagnetic hysteresis.   * + - 1. **From microscopic to macroscopic**   Transition from microscopic to macroscopic as consequence of theory probability. Einstein solid and particle in box models. Temperature demon algorithm. Practical: Equilibrium of particle in box model. Thermodynamic equilibrium and temperature of Einstein solid.   * + - 1. **The chemical potential and phase equilibria** The Chemical potential of Einstein solid. The chemical demon algorithm, Widom insertion method. Practical: The excess chemical potential of a Lennard-Jones fluid. The chemical potential of a one-dimensional ideal gas,  the effects of interparticle interactions. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Numerical Methods of Quantum Physics*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 18 |
| ***Number of Seminar and Practical Assignment Hours*** | 14 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 18.03.2021 |
| ***Course Developer*** | Dr.chem. Ģirts Barinovs |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to learn to recognize physical problems that can to be analysed by numerical methods of quantum physics, to learn to perform quantum chemical calculations, to learn to interpret the results of the calculations performed by you or other scientists.  Tasks of the course are to:   1. understand the laws of quantum mechanics required for description atoms and for the calculation of molecular properties; 2. understand the main approximations in the description of the electronic structure, to control the accuracy of approximations made, to be able to suggest how to improve accuracy of results, to take into account the limits set by technology used; 3. be able to create an input file for a standard quantum chemical calculation; 4. calculate the electronic structure of atoms and molecules using ab initio and semi-empirical calculation methods using wave function or density functional approach; 5. perform a theoretical study calculating physical and chemical properties of molecules and present the results. To choose the best approximation for calculations, to analyze the results, their accuracy, to summarize the experimental and theoretical information from the scientific literature, to compare it with your calculation results.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Formulates and explain the basic equations and related approximations for the many-electron calculation and the movement of atoms; 2. Names the main methods of calculations, they explain the advantages and disadvantages of the methods;   Skills:   1. Practically applies numerical methods of quantum physics to calculations of many-electron systems; 2. Interprets and presents the obtained results;   Competence:   1. Chooses appropriate method of the numerical calculation of many-electron system; 2. Chooses an appropriate approximation, evaluate the calculation feasibility; 3. Estimates the necessary computer resources and evaluate the calculation time, run the calculations; 4. Interprets the obtained results and their accuracy; 5. Offers realistic approach for the improvement of the obtained results. | |
| ***Course Plan*** | |
| 1. Schrodinger equation and applications. L2 2. Wavefunction of electrons. L2 P2 3. Hydrogen molecule. L2 P2 4. One-electron approximation. L2 P2 5. Propagation of wavepackets. L2 P2 6. Electron correlation. L4 P2 7. Density functional theory. L2 P2 8. Calculation of interatomic interaction. P2 9. Quantum continuum methods. L2   L – lecture, P - practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is organized individually. Students are advised to cluster into small study groups, however, at the end submitting only the results of their individual work at homework and examinations.  Independent tasks are to:  1. study literature related to the topics of the study course.  2. analyze the mistakes made during the lectures (mistakes made during exercises or during the group work) and to address causes of the mistakes.  3. prepare for the exam.  4. complete 6 homework.  5. be able to repeat the calculations made in practical work at home. To perform independent calculations for the description of the research problem agreed with the lecturer, independently choosing the numerical method, interpreting the results and improving the accuracy of the results.  6. prepare a presentation of your calculation. | |
| ***Requirements for Awarding Credits*** | |
| During the course students will solve problems using PC to calculate properties of different molecules, liquids and solids.  Intermediate tests:   1. 7 practical calculations and 6 homework exercises - 20% 2. Presentation of calculation - 40%   Final examination:   1. Exam (written) - 40% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | | 1. Practical calculations and homework exercises | x | x | x | x | x | x | x | x | X | | 1. Presentation of calculation |  |  | x | x | x | x | x | x | x | | 1. Final written exam | x | x |  |  |  |  |  |  |  | | |
| ***Compulsory Reading List*** | |
| 1. Āboliņš, J., Šilters, E. Vielas uzbūve : teorētiskās fizikas un kvantu ķīmijas nodaļas : mācību līdzeklis augstskolu ķīmijas fakultāšu studentiem, Rīga : Zvaigzne, 1970, 284, [1] lpp. : il. 2. Miķelsons, J., Rolovs, B., Šilters, E.,; Rolova, B. red., Kvantu mehānika : mācību līdzeklis universitāšu un pedagoģisko institūtu fizikas un matemātikas fakultāšu studentiem, Rīga : Zvaigzne, 1970, 354, [1] lpp. : il., graf. 3. Szabo, A., Ostlund, N.S. ,Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory, Dover Books, (1982). | |
| ***Further Reading List*** | |
|  | |
| ***Periodicals and other sources*** | |
| 1. Burke, K, The ABC of DFT (2007), <http://www.chem.uci.edu/~kieron/dftold2/materials/bookABCDFT/gamma/g1.pdf> 2. From nano to macro: Introduction to atomistic modeling techniques. Lecture notes (2005) http://web.mit.edu/mbuehler/www/Teaching/LS/ | |
| ***Course Content*** |  |
| **Topic 1. Quantum mechanics. Postulates of quantum mechanics. Schrödinger's equation** (lecture 2 hours)  Quantum chemistry. Its development and applications. Quantum chemical calculation programs. Basic postulates of quantum mechanics. Time-dependent Schrödinger equation.  **Topic 2. Schrödinger's equation**  (lecture - 2 hours)  Time-independent Schrödinger equation. Electron and nuclear coordinates. Many-electron Hamiltonian. Born-Oppenheim approximation and limits of its applicability.  1. homework on the topic covered in the lesson.  **Topic 3. Hydrogen atom and single electron wave function**.  (lecture - 2 hours)  Analytical representations of the electron wave function using an analytical solution for a hydrogen atom. Visualization of wave functions in Mathematica system.  2. homework on the topic covered in the lecture.  **Topic 4. Electron wave functions.**  (lecture - 2 hours, practical work - 2 hours)  Slater and Gaussian type basic functions. Their advantages, disadvantages and application in the case of hydrogen atom. Diffuse functions. Polarization functions.  3. homework on the topic covered in the lecture.  Practical work 1: Introduction to GAMESS US calculations, interpretation and visualization of numerical results  **Topic 5. Variational principle**  (lecture - 2 hours, practical work - 2 hours)  Variational principle. Application of the principle to a hydrogen atom using Gaussian type orbitals.  4. homework on the topic covered in the lesson.  2. practical work: Convergence of GAMESS US calculations using variational methods with different base sets.  **Topic 6. One electron approximation**.  (lecture - 2 hours, practical work - 4 hours)  One electron approximation. Slater determinant. Hartry-Fock method. Coulomb and exchange integral, interaction potential. Koopman's theorem.  5. homework on the topic covered in the lesson  3. practical work: hydrogen molecules and the calculation of the excited states.  4. practical work: description of many-electron atoms  **Topic 7 Electron correlation.**  (lecture - 2 hours, practical work - 4 hours)  Many-electron atoms. Electron-electron correlation. Description of molecules. Perturbation theory. Configuration interaction. Coupled cluster method.  6. homework on the topic covered in the lesson  5. practical work: Application calculations in calculation of of electron correlation, molecular geometry and spectroscopic properties.  6. practical work: System symmetry and computational efficiency. Use of Z matrix in input of geometry  **Topic 8. Density functional method.**  (lecture - 2 hours, practical work - 2 hours)  Density functional method. Energy functionals. Their advantages and limits of applicability.  7. practical works: Applications of the density functional method  **Topic 9. Application of numerical methods**  (lecture - 2 hours)  Presentation of research projects. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***High-Performance Computing in Physics*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 16 |
| ***Number of Seminar and Practical Assignment Hours*** | 0 |
| ***Number of Laboratory Work Hours*** | 16 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.sc.ing. Andris Guļāns |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to create an insight into high-performance computing in Physics.  The tasks of the course are:   1. To overview applications of parallel algorithms in Physics problems, 2. To overview methods of parallel computing, 3. To learn how to use high-performance libraries, 4. To analyse efficiency of parallel algorithms, 5. To gain an experience in using supercomputing centres.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Describes performance of scientific software and its limiting factors; 2. Understands parallel computing and the related main approaches: vectorisation, multi-threaded programming and MPI;   Skills:   1. Analyzes the parallel efficiency using the concepts of speed-up and scalability; 2. Runs calculations in a supercomputing centre;   Competence:   1. Programs in FORTRAN; 2. Analyzes and evaluates standard tasks (linear systems, eigenvalue problem, Fourier transformation) in a given problem and to related high-performance libraries; 3. Applies parallel methods for studying physical phenomenal. | |
| ***Course Plan*** | |
| 1. Introduction, concept of scientific computing, LINUX environment. L2 2. FORTRAN programming language. L2 Ld2 3. Parallel computing, kinds of parallelism. L2 4. Vectorisation of arithmetic operations. L2 Ld2 5. Multi-threaded programming – OpeenMP. L2 Ld4 6. Parallelism in architectures with non-uniform memory access - MPI L4 Ld4 7. High-performance libraries. L2 Ld2 8. Using supercomputing centres. L2   L – lecture, Ld - laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| During the course students receive lab assignments. Every assignment is completed partially during exercise sessions, partially individually. Every work is graded on a scale from 0 to 10. Successful completion of the assignments is a prerequisite for taking part in the exam. | |
| ***Requirements for Awarding Credits*** | |
| Final mark consists of:  Intermediate tests:   1. Lab assignments (6) - 75%   Final examination:   1. Exam (written) - 25% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1. Lab assignements (6) | + | + | + | + | + | + | + | | 1. Exam | + | + | + |  | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Thijssen, J.M. Computational Physics 2. Trobec, R., Slivnik, B., Bulić, P., Robič, B. Introduction to Parallel Computing | |
| ***Further Reading List*** | |
| 1. FORTRAN documentācija, https://software.intel.com/en-us/fortran-compiler-developer-guide-and-reference-language-reference 2. LAPACK dokumentācija, http://www.netlib.org/lapack/explore-html/ 3. Open MPI dokumentācija, https://www.open-mpi.org/doc/current/ 4. OpenMP standarts, https://www.openmp.org/wp-content/uploads/OpenMP-API-Specification-5.0.pdf 5. Press, W.H. (Autor), Teukolsky, S.A., Vetterling, W.T., Flannery, B.P.Numerical Recipes: The Art of Scientific Computing 6. ScaLAPACK dokumentācija, http://www.netlib.org/scalapack/explore-html/ 7. Thijssen, J.M. Computational Physics | |
| ***Periodicals and other sources*** | |
| 1. The Parallel Universe Magazine, https://software.intel.com/en-us/parallel-universe-magazine | |
| ***Course Content*** |  |
| 1. Introduction. Concept of scientific computing. Concept of parallel computing. Application of parallel algorithms for solving physics problems. 2. LINUX environment. Remote computing. 3. FORTRAN programming language. Compiling, linking libraries. Example: calculating pi using the Monte-Carlo method. 4. Parallel computing. Overview in kinds of parallelism and related computer architectures. Processor's theoretical peak performance. Scalability of parallel programs. 5. Vectorisation of arithmetic operations. SSE and AVX technologies. Automatic vectorisation supported by compilers. Example: matrix multiplication. 6. Multi-threaded programming (OpenMP). OpenMP directives in FORTRAN. Loop parallelisation. Limiting factors in multi-threaded performance. Examples: calculating pi using the Monte-Carlo method, phase transitions in the Ising model. 7. Parallelization in distributed memory architectures (MPI). Data exchange between compute nodes. Examples: calculating pi using the Monte-Carlo method, phase transitions in the Ising model. 8. High-performance libraries. LAPACK, ScaLAPACK. 9. Using supercomputing centres. Queueing systems and resource sharing. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Methods of Mathematical Physics*** |
|  | Mathematics |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 32 |
| ***Number of Seminar and Practical Assignment Hours*** | 32 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 22.02.2021 |
| ***Course Developer*** | Dr. math. Jānis Bajārs, Dr. phys. Jānis Cīmurs |
| ***Prerequisite Knowledge*** | Mate1050, Mate1051, Mate2024, Mathematical analysis I, II un III  Mate2013, Differential equations  Mate3012, Methods of Mathematical Physics I |
| ***Study Course Abstract*** |  |
| The aim of the course is to deliver broad knowledge on theoretical foundations of methods of mathematical physics and on practical solution techniques using mathematical software, such as MATLAB and MATHEMATICA .  Tasks of the course are:   1. to get acquainted with theoretical questions in mathematical physics; 2. to gain notion of common problem solution methods; 3. to master leading mathematical software packages, such as MATLAB and MATHEMATICA; 4. to solve physics problems using mathematical software.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Identifies orthogonal functions, function series and integral transforms, and their theoretical and practical applications; 2. Understands eigenvalue (spectral) problems of linear differential operators and their use for differential equations; 3. Identifies Sturm–Liouville equation and special functions; 4. Understands applications and analytic methods for partial differential equations (wave, heat, Poisson’s equation, etc.); 5. Understands applications and use of calculus of variations; 6. Explains mathematical software to tackle the listed problems above;   Skills:   1. Expands functions into orthogonal function series, applying and using integral transforms to analyse function properties and solve differential equations; 2. Addresses an eigenvalue problem of linear differential operators as a method for solving differential equations; 3. Solves partial differential equations using the method of characteristics and the separation of variables method; 4. Solves the Euler-Lagrange equation to find a function that minimises a functional; 5. Uses mathematical software for solving the problems above;   Competence:   1. Applies the most suited mathematical description for a particular physical problem; 2. Critically evaluates and choses the most optimal mathematical software tools to solve the problems of mathematical physics either symbolically or numerically. | |
| ***Course Plan*** | |
| 1. Orthogonal functions and Fourier series. L2 Ld2 2. Fourier and Laplace transforms. L6 Ld6 3. Eigenvalue problem of linear differential operators; Hermitian operator and its properties. L4 Ld4 4. Sturm–Liouville equation, Green’s function and special functions. L6 Ld6 5. Partial differential equations and analytical methods for the first order equations. L4 Ld4 6. Second order partial differential equations and the separation of variables method. L6 Ld6 7. Calculus of variations. L4 Ld4   L – lecture, Ld - Laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' work is organized as independent work.  Practical tasks:   1. Study the course’s related literature; 2. Prepare for seminars by learning mathematical software; 3. Solve theoretical and practical exercises. | |
| ***Requirements for Awarding Credits*** | |
| Students have to obtain knowledge of theoretical questions as well as practical skills by solving applied mathematics and mathematical physics problems using mathematical software.  Intermediate tests:  1. intermediate test Nr.1: laboratory work – 15%  2. intermediate test Nr.2: laboratory work – 15%  3. intermediate test Nr.3: laboratory work – 15%  4. intermediate test Nr.4: laboratory work – 15%  Topics:   * 1. Function approximations and integral transforms with applications;   2. Eigenfunction methods for differential equations;   3. Mathematical modelling and analytical methods for partial differential equations;   4. Numerical solutions of wave, heat and Poisson’s equations.   Final examination:   1. Exam (written) – 40%   In order to pass the course, students have to pass both elements where the average grade of all four assignments is considered for element 1. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | | 1. intermediate test: laboratory work | + |  |  |  |  | + | + |  |  |  | + |  | + | | 2. intermediate test: laboratory work |  | + | + |  |  | + |  | + |  |  | + |  | + | | 3. intermediate test: laboratory work |  |  |  | + |  | + |  |  | + |  | + |  | + | | 4. intermediate test: laboratory work |  |  |  | + |  | + |  |  |  |  | + |  | + | | 5. Exam | + | + | + | + | + |  | + | + | + | + |  | + |  | | |
| ***Compulsory Reading List*** | |
| 1. Arfken, G.B., Weber, H.J. *Mathematical Methods for Physicists*. Amsterdam [etc.] : Elsevier Academic Press, 2005. (24 eks.) 2. Riley, K.F., Hobson, M.P., Bence, S.J. *Mathematical methods for physics and engineering*. Cambridge; New York : Cambridge University Press, 2006. (12 eks.) | |
| ***Further Reading List*** | |
| 1. Buiķis, A. *Matemātiskās fizikas vienādojumi: pamatjautājumi*. Rīga : Latvijas Universitāte, 2003. (35 eks.) 2. Young, E.C. *Partial differential equations : An introduction*. Boston : Allyn and Bacon, 1972. (1 eks.) 3. Kalis, H., Lācis, S., Lietuvietis, O., Pagodkina, I. *Programmu paketes “Mathematica” lietošana mācību procesā : mācību līdzeklis*. Rīga : Mācību grāmata, 1997. (38 eks.) 4. Logan, J.D. *Applied mathematics*. Hoboken, N.J. : Wiley-Interscience, c2006. (1 eks.) 5. Pinchover, Y., Rubinstein, J. *An introduction to partial differential equations*. Cambridge : Cambridge University Press, 2005. (1 eks.) 6. Quarteroni, A., Saleri, F. *Scientific computing with Matlab and Octave*. Berlin; Heidelberg; New York : Springer, c2006. (11 eks.) 7. Riekstiņš, E. *Matemātiskās fizikas vienādojumi: mācību līdzeklis Latvijas Valsts universitātes Fizikas un matemātikas fakultātē*. Rīga : LVI, 1964. (38 eks.) 8. Wolfram, S. *An Elementary Introduction to the Wolfram Language*. Wolfram Media; 2nd. Edition, 2017. (Pieejams internetā: [www.wolfram.com](http://www.wolfram.com/).) | |
| ***Periodicals and other sources*** | |
|  | |
| ***Course Content*** |  |
| 1. lecture. Definition and examples of orthogonal functions. Fourier series, properties and examples with applications.  1. practical. Fourier series expansion of a function.  2. lecture. Fourier transform and properties. Parseval’s theorem.  2. practical. Fourier transform of a function with mathematical software.  3. lecture. Applications of Fourier transform, e.g., spectrogram.  3. practical. Spectrogram and its applications.  4. lecture. Laplace transform with applications to ordinary differential equations.  4. practical. Laplace transform of a function with mathematical software.  5. lecture. Eigenvalue (spectral) problem of linear differential operators as a method for solving differential equations.  5. practical. Eigenfunction calculations of differential operators.  6. lecture. Hermitian operator and its properties.  6. practical. Solutions of ordinary differential equations using symbolic mathematical software.  7. lecture. Sturm–Liouville equation and special solutions.  7. practical. Examples and solutions of Sturm–Liouville equation.  8. lecture. Green’s function and its applications.  8. practical. Green’s function applications to the two-point boundary value problems.  9. lecture. Special functions.  9. practical. Using properties of special functions.  10. lecture. Introduction to partial differential equations, general and particular solutions with examples and applications.  10. practical. Analytical solutions of the first order partial differential equations.    11. lecture. The method of characteristics for the first order partial differential equations.  11. practical. Analytical solutions of the first order partial differential equations, continuation.  12. lecture. Second order partial differential equations; wave and heat equations.  12. practical. Analytical solutions of the second order partial differential equations with mathematical software.  13. lecture. Poisson’s equation and the separation of variables method.  13. practical. Analytical and numerical solutions of the second order partial differential equations with mathematical software.  14. lecture. Partial differential equations in polar and cylindrical coordinates.  14. practical. Numerical solutions of the second order partial differential equations with mathematical software.  15. lecture. Introduction to the calculus of variations.  15. practical. Computation of the function that minimizes a functional.  16. lecture. Calculus of variations with constraints.  16. practical. Computation of the function that minimizes a functional with constraints. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Stochastic Processes*** |
|  | Mathematics |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 40 |
| ***Number of Seminar and Practical Assignment Hours*** | 24 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 12.05.2011 |
| ***Course Developer*** | Dr. math., Jānis Valeinis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education |
| ***Study Course Abstract*** |  |
| The aim of the study course is to learn the theoretical bases of stochastic processes by looking at different applications in probability theory, mathematical statistics, physics, chemistry, biology and other fields with practical implementation done using the program R.  Study course tasks:   1. To deeply analyze classical random walk stochastic process, an introduction of discrete and continuous time Markov processes as well as Brownian motion, Poisson process and general diffusion processes; 2. To analyze different applications:  * in financial mathematics, describing the famous Black-Scholes model; * in physics, describing the Floker-Plank and Langevin equations.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Identifies classical stochastic processes and their characteristics; 2. Understands processes of a discrete and continuous Markov chains; 3. Understands applications of random processes in financial mathematics and physics;   Skills:   1. Recognizes different stochastic process models and be able to apply them to practical data problems; 2. Analyzes different processes using the program R; 3. Analyzes scientific literature that uses stochastic processes;   Competence:   1. Integrates stochastic process modelling into independent scientific and applied research; 2. Justifies theoretical studies carried out in math, physics and other areas where stochastic process modelling is to be applied. | |
| ***Course Plan*** | |
| 1. Basics of probability theory. L2 P2 2. Random variables and their distributions. L2 P2 3. Generating functions and their applications. L2 P2 4. Markov chains in discrete and continuous case. L4 P2 5. Random walk and its characteristics. L4 P2 6. Branching processes. Birth-death processes. Poisson process. L4 P2 7. Stationary processes, spectral representation and ergodic theorem. Gaussian processes. L4 P2 8. Martingales, stopping times and optional stopping. L2 P2 9. Diffusion processes. Brownian motion. L4 P2 10. Stochastic calculus. Ito formula and Black-Scholes formula. L4 P2 11. Master and Focker-Planck equations. L4 P2 12. Ornstein-Uhlenbeck processes, Langevian equation. L4 P2   L - lecture, S - seminar, P - practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| 1. To study literature related to the subjects of the study course; 2. Preparing for workshop lessons by analysing scientific papers; 3. To make a presentation twice; 4. Homeworks to be submitted within the time limits assigned. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Homework - 25% 2. Presentation in a seminar on scientific publication - 25%   Final examination:   1. Exam (oral) - 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | | 1. Homeworks | X | X | X |  | X | X |  | X | | 1. Presentations | X | X |  | X | X | X | X | X | | 1. Exam | X | X | X |  |  |  |  |  | | |
| ***Compulsory Reading List*** | |
| 1. Grimmett, G.R., Stirzaker, D. Probability and random processes. Oxford university press, 2001 2. Kampen, V., Godfried, N. Stochastic processes in physics and chemistry. Vol. 1. Elsevier, 1992 | |
| ***Further Reading List*** | |
| 1. Lemons, D. S., Langevin, P. An introduction to stochastic processes in physics. JHU Press, 2002. 2. Melvin, L., Cai, W., Xu, M. Random processes in physics and finance. Oxford University Press, 2006. 3. Ross, S.M., et al. Stochastic processes. Vol. 2. New York: Wiley, 1996. | |
| ***Periodicals and other sources*** | |
| 1. Class M: Simulation, stochastic modeling, http://gams.nist.gov/serve.cgi/Class/M/ 2. Random Processes II, http://www.winlab.rutgers.edu/~crose/545\_html/stochastic2/node1.html 3. Stochastic process, <http://en.wikipedia.org/wiki/Stochastic_process> | |
| ***Course Content*** |  |
| **1. Basics of probability theory**  The most important concepts of probability theory required for this course will be repeated. More specifically, events, combinatorics, classical probability, the concept of probability sppce will be considered. Stochastic convergence, the law of large numbers and the central limit theory will be presented as well.  Practical exercises. Various excersises related to the basic concepts of probability theory will be addressed.  2. Random variables and their distributions  Random variables, their characteristics, measures of central tendency and variance measures. Different examples of discrete and continuous distributions. The relationship between binomial and normal distribution will be discussed. Multivariate normal distribution and dependence concept between variables.  Practical exercises. Various tasks related to random variables, their characteristics and different distributions will be considered.  3. Generating functions with applications  Generating functions and their charasteristics. Applications mainly for a simple random walk and branching processes. Moment generating and characteristic functions with examples.  Practical works. Various tasks related to generating functions and their applications will be addressed.  4. Markov chains in discrete and continuous time  Discrete Markov chains, definitions and examples. Classification of states. Kolmogorov-Chapman equations. Stationary distribution and convergence theorem. Continuous time Markov chains, examples.  Practical exercises. Various tasks related to Markov chains will be examined in discrete and continuous times. The R program will be used for practical examples.  5. Random walk and its characteristics  Simple random walk in discrete time. Recurrence of random walk in one, two and three dimensions. Different characteristics of a random walk (gambling bankruptcy, ballot theorem, arcsin law etc.).  Practical exercises. Various tasks related to a simple random walk will be considered.  6. Branching processes. Birth and death processes. The Poisson Process.  Poisson process definition with practical examples. General branching, birth and death processes, their characteristics, different theorems and examples.  Practical exercises. Various tasks related to Poisson, branching and birth processes will be examined. Real datasets in program R will be discussed.  7. Stationary processes, process spectral representation and ergodic theorem.  Stationary processes, their characteristics. Autocovariance function, spectrum. Periodogram and discrete Fourier transformation. Spectral representation of stationary processes. Definition and examples of ergodic theorem and Gaussian processes.  Practical exercises. Exercises about stationarity and autocovariance functions of some known processes (such as classical ARMA(p,q) processes) and their spectral representations. Program R will be used analyzing autocovariance and periodogram functions for real data examples.  8. Martingales and stopping times.  The definition of martingales in discrete and continuous time with examples. Filtration concept. The concept of stopping time and convergence theorem.  Practical exercises. Exercises about conditional expectation, filtrations and martingales.  9. Diffusion processes and Brown motion.  General definitions of diffusion processes and Brownian motion. Relationship between random walk and Brownian motion. Partial differential equations for diffusion processes.  Practical exercises. The tasks of finding diffusion using partial differentials will be addressed. Simulations in program R.  10. Stochastic analysis. Ito formula and Black-Scholes formula.  An insight into the theory of stochastic integrals will be provided. Ito formula and Black-Scholes formula for option pricing. Basic concepts of shares, obligations and options.  Practical exercises. The theoretical tasks of using the Ito formula will be considered. Real data examples in program R.  11. Master and Fokker-Planck equations.  Basic concepts of Master and Fokker-Planck equations describing the probabilistic behavior of particles with examples from different fields.  Practical exercises. Examples and applications of Master and Fokker-Planck equations. Simulations in program R.  12. Langevin equations, Ornstein-Uhlenbeck process.  Basic concepts of Langevin equations. Stochastic differential equations. Basic concepts and example of Ornstein-Uhlenbeck process.  Practical exercises. Different simulations and data examples in program R. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | ***Complex Analysis*** |
|  | Mathematics |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 16 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 04.03.2021 |
| ***Course Developer*** | Dr.math. Svetlana Asmuss |
| ***Prerequisite Knowledge*** | |  |  | | --- | --- | | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education |  | |
| ***Study Course Abstract*** |  |
| The aim of the study course is to give an introduction to the theory of functions of a complex variable and to acquaint students with examples of application of methods based on functions of a complex variable in physics.  Tasks of the study course are:   1. to get an introduction to the selected chapters of the theory of functions of a complex variable (complex plane, function of a complex variable, its derivative, integral, singularities and residue, Taylor and Laurent series); 2. to learn to use differentiation and integration techniques for functions of a complex variable; 3. to gain experience in the use of methods based on functions of a complex variable in solving some problems in physics.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Identifies functions of a complex variable and their derivatives; 2. Understands integrals of functions of a complex variable; 3. Identifies Taylor and Laurent series in complex domain; 4. Understands examples of physical applications of functions of a complex variable;   Skills:   1. Solves problems on functions of a complex variable and their derivatives; 2. Solves problems on integrals of functions of a complex variable; 3. Solves problems on Taylor and Laurent series in complex domain; 4. Illustrates notions and results of Complex Analysis based on physical applications;   Competence:   1. Chooses and applies in physics methods based on functions of a complex variable, on their derivatives, integrals and series. | |
| ***Course Plan*** | |
| 1. Complex plane. L1, P2 2. Elementary functions of a complex variable. L2, P2 3. Differentiation of functions of a complex variable with applications. L4, P4  Integration in complex domain, Cauchy integral theorem and its application. L2, P4 4. Taylor and Laurent series with applications. L2, P2 5. Singularities and residue of complex functions with applications. L2, P2 6. Tests. T3   L – lecture, P – practical tasks, T - test | |
| ***Characterization of students' independent work organization and tasks*** | |
| Student's independent work organization: individual practical exercises | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Tests - 30% 2. Individual practical exercises - 20%   Final examination:   1. Exam (oral) - 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | | 1. Test | x |  |  | x | x |  |  | x |  | | 1. Test |  | x |  | x |  | x |  | x |  | | 1. Test |  |  | x | x |  |  | x | x |  | | 1. Homework | x | x | x | x | x | x | x | x | x | | 1. Exam | x | x | x | x | x | x | x | x | x | | |
| ***Compulsory Reading List*** | |
| 1. Olver, P. Complex Analysis and Conformal Mappings, 2018 Available: <http://www-users.math.umn.edu/~olver/ln_/cml.pdf> 2. Riley, K., Hobson, M., Bence, S. Mathematical Methods for Physics and Engineering. Cambridge University Press, 2008 | |
| ***Further Reading List*** | |
| 1. Berg, C. Complex Analysis, 2012 Available: <http://web.math.ku.dk/noter/filer/koman-12.pdf> 2. Cain, G. Complex Analysis, 2001 Available: http://www.math.gatech.edu/~cain/winter99/complex.html 3. Chen, W. Introduction to Complex Analysis, 2003 Available: http://www.maths.mq.edu.au/~wchen/lnicafolder/lnica.html 4. Cīrulis, T., Cīrule, D. Kompleksā mainīgā funkciju teorija. I, II. Rīga, LU, 2003 5. Reinfelds, A. Kompleksi mainīgā funkciju teorija. | |
| ***Periodicals and other sources*** | |
| 1. Complex Analysis and Operator Theory, SCI Journal, Springer 2. Journal of Complex Analysis, Hindawi | |
| ***Course Content*** |  |
| 1. Complex plane   (3 hours: L1+P2)  Complex numbers and complex plane. Manipulation with complex numbers in the algebraic, polar and exponential form of representation.  2. Elementary functions of a complex variable  (4 hours: L2+P2)  Elementary functions of a complex variable: linear functions, polynomials and rational functions, exponential, hyperbolic and trigonometric functions, complex logarithms and complex powers, inverse trigonometric and hyperbolic functions.  3. Differentiation of functions of a complex variable with applications  (8 hours: L4+P4)  Derivatives of functions of a complex variable. Cauchy-Riemann equations as necessary and sufficient conditions for differentiation. Modulus and argument of derivatives, their interpretation. Conformal mappings. Laplace equation, harmonic functions, their representation by complex functions. Examples of applications of functions of a complex variable in hydrodynamics and electromagnetism. Flow past an airfoil, electric field around capacitors.  4. Integration in complex domain, Cauchy integral theorem and its application  (6 hours: L2+P4)  Integration of functions of a complex variable. Cauchy integral theorem. Cauchy integral formula. Derivatives by integration. Circulation and lift.  5. Taylor and Laurent series with applications  (4 hours: L2+P2)  Power series in complex domain, the radius and circle of convergence. Taylor and Laurent expansions of functions of a complex variables. Applications of Taylor and Laurent series.  6. Singularities and residue of complex functions with applications  (4 hours: L2+P2)  Singularities of functions of a complex variable, their classification. Isolated non-essential singularities. Residue. Residue theorem. Examples of residue applications. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- | --- |
| ***Study Course Title*** | ***Atomic and molecular processes*** | |
|  | Physics and astronomy | |
| ***Credits*** | 2 | |
| ***Total Number of Contact Hours*** | 32 | |
| ***Number of Lecture Hours*** | 32 | |
| ***Number of Seminar and Practical Assignment Hours*** | 0 | |
| ***Number of Laboratory Work Hours*** | 0 | |
| ***Independent Study Hours*** | 48 | |
| ***Course Approval Date*** | 20.04.2021 | |
| ***Course Developer*** | Dr.habil.phys. Ruvins Ferbers  Dr.habil.phys. Mārcis Auziņš  Dr.phys. Aigars Ekers | |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. | |
| ***Study Course Abstract*** |  | |
| The aim of the study course is to create an idea and develop students' understanding of the interaction of atoms and molecules with light and its applications in modern physics.    Tasks of the study course are:   1. To get acquainted with the physical bases and processes that determine and explain the interaction of atoms and molecules with light; 2. To acquire skills to analyze and solve problems in the field of experimental research of atomic and molecular processes; 3. To get acquainted with the possibilities to use the obtained ideas about atomic and molecular phenomena in quantum technologies.   Languages of instruction are Latvian and English. | | |
| ***Learning Outcomes*** |  | |
| Knowledge:   1. Understands the physical phenomena and processes, which determine and explain the interaction of atoms and molecules with light; 2. Explains production and application of atoms and ions at ultra-low temperatures;   Skills:   1. Analyzes and solves problems and tasks in the field of experimental studies of atomic processes by applying modern laser spectroscopy methods; 2. Analyzes and solves problems and tasks in the field of experimental studies of molecular and cluster processes by applying modern laser spectroscopy methods;   Competence:   1. Applies the obtained knowledge regarding the processes and phenomena on atomic and molecular level for describing contemporary and future applications in quantum technologies; 2. Applies the obtained knowledge regarding the processes and phenomena to molecules and clusters for describing contemporary and future applications in quantum technologies. | | |
| ***Course Plan*** | | |
| 1. Atoms interaction with light. Light absorption and emission processes. Einstein coefficients, their connection with Planck formula. L2 2. Transition dipole moment from classical and quantum physics point of view, its connection with Einstein coefficients. State's lifetime, its measurements. Determination of collision process rate parameters. L2 3. Transition matrix element, selection rules for absorption and emission processes. L2 4. Atomic processes in external electric and magnetic fields. Interference of coherent states. L4 5. Spectral contours of atomic transitions (spectral lines) and their broadening in various processes. L2 6. Atomic processes which are connected with cooling and trapping of neutral atoms by applying laser irradiation and external fields. Bose-Einstein condensation. Principles of atomic interferometry. L4 7. Ion trapping. Ion traps, there build-up and analysis of processes. Laser cooling of trapped ions. L2 8. Structure of diatomic molecules and their interaction with light. Intermolecular processes. L2 9. Electronic, vibration and rotation processes in diatomic molecules. Molecular states and spectra. L4 10. 1Dynamics of molecular processes. Notion of vibrational wave-package and its evolution. Processes of atomic and molecular collisions, their studies by laser spectroscopy methods. L2 11. Chemical reactions, their classification. Reaction rate and rate constant. Collisional complex and collisional control of a chemical reaction. L4 12. Clusters, their formation and studies. L2   L – lecture | | |
| ***Characterization of students' independent work organization and tasks*** | | |
| 1. To study the literature related to the study course topics; 2. To prepare for the planned lesson following the teacher's instructions; 3. Prepare an essay on one of the course topics; 4. Answer test questions regularly. | | |
| ***Requirements for Awarding Credits*** | | |
| Attendance of all lectures is likely desirable. The total evaluation has to be at least 4 (up to 10) to pass. Course examination (it forms 50% of overall evaluation) is oral; it includes three questions on different topics from lecture course curriculum. The evaluation is an average of the three questions. It is allowed to use tables of physical constants and mathematical handbooks, as well as original scientific papers during the examination.  Intermediate tests:   1. Test 1 - 25% 2. Test 2 - 25%   Final examination:   1. Exam (oral) - 50% | | |
| ***Criteria for Evaluation Learning Outcomes*** |  | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Test 1 | + |  | + |  |  |  | | 1. Test 2 |  | + |  | + |  |  | | 1. Exam |  |  | + | + | + | + | | | |
| ***Compulsory Reading List*** | | |
| 1. Demtröder, W. Atoms, Molecules and Photons. Springer-Verlag, Berlin, Heidelberg, 2006. 2. Demtröder, W. Laser Spectroscopy. Basic concepts and instrumentation. Springer-Verlag, Berlin, Heidelberg, 2003. 3. Foot, Ch. Atomic Physics. Oxford University Press, Oxford, New York, 2005. | | |
| ***Further Reading List*** | | |
| 1. Auzinsh, M., Ferber, R. Optical Polarisation of Molecules, Cambridge University Press, Cambridge, 2005 2. Levebvre-Brion, H., Field, R.W. The Spectra and Dynamics of Diatomic Molecules, Elsevier, 2004 3. Metcalf, H. Van der Straten, P. Laser Coolong and Trapping, Springer, 1999 4. Svanberg, S. Atomic and Molecular Spectroscopy, Springer-Verlag, 2004 | | |
| ***Periodicals and other sources*** | | |
| 1. Nature 2. Physics Today 3. Science | | |
| ***Course Content*** |  | |
| 1. **Atoms interaction with light. Light absorption and emission processes. Einstein coefficients, their connection with Planck formula.**   Absorption, spontaneous and induced emission processes; Einstein coefficients. Dynamic equilibrium condition, relationship between Aik and Bik coefficients, the link to Planck formula. [1], [2], [3].   1. **Transition dipole moment from classical and quantum physics point of view, its connection with Einstein coefficients. State's lifetime, its measurements. Determination of collision process rate parameters.**   Transition probabilities, their connection to radiation power. The rate of decay of the excited state (decay constant) from the point of view of classical and quantum physics; lifetime measurement and determination of the rate constant of collision processes. [1], [2].   1. **Transition matrix element, selection rules of absorption and emission processes.**   Conservation of angular momentum in atomic transition processes. Transition matrix elements and magnetic quantum number *m* selection rules for the absorption and emission of circular and linearly polarized radiation; the role of the direction of observation. Selection rules for the orbital quantum number *l*. [1], [3].   1. **Atomic processes in external electric and magnetic fields. Interference of coherent states.**   Stark effect, level crossing in external electric field. Zeeman effect, its relation to light polarization and excitation-observation geometry. Level crossing in an external magnetic field. Hanle effect, its classical and quantum explanation. Interference of coherent states (quantum oscillations or quantum "beats". The coherence of magnetic sublevels, dark and bright resonances, examples (Rb, Cs atoms). [1], [2], [3], [4], [6].   1. **Spectral contours of atomic transitions (spectral lines) and their broadening in various processes.**   Processes leading to the broadening of spectral lines. Natural or Lorentzian-shape spectral profiles from the point of view of classical and quantum physics. Doppler effect, Doppler or Gaussian spectral profile in case of Maxwell distribution. Mixed Gaussian and Lorentzian profile. Broadening and shifting of the spectral profile due to collisional processes. [1], [2].   1. **Atomic processes which are connected with cooling and trapping of neutral atoms by applying laser irradiation and external fields. Bose-Einstein condensation. Principles of atom interferometry.**   Deceleration of atomic velocities by laser radiation in the absorption-emission process due to the photon reaction. Evaluation of photon reaction force and number of absorption-emission acts per second, cooling temperature limit, examples. Deceleration of atomic velocities in an atomic beam. Optical cooling in three dimensions, optical molasses. Processes in magneto-optical traps (MOTs), atomic capture in MOT, examples. Bose - Einstein condensation, its conditions, cooling in the evaporation process in a magnetic trap. Properties of Bose - Einstein condensate, its applications. The concept of atom interferometry and atomic lasers. [1], [2], [3], [7].   1. **Ion trapping. Ion traps, there build-up and analysis of processes. Laser cooling of trapped ions.**   Problems with trapping charged particles in a constant electrostatic field and possibilities to ensure dynamic balance with a changing field. Analysis of Paul (*W. Paul*) ion traps, their basic construction ideas and processes. Laser cooling of trapped ions. Applications: ion crystals, quantum jumps, frequency standards. [1], [2], [3].   1. **Structure of diatomic molecules and their interaction with light. Intermolecular processes.**   Processes in diatomic molecules. Formation of diatomic molecules from atoms, binding potential, its representation with the Morse potential energy curve. Structure, spectra and dynamics of diatomic molecules. Types of motion in diatomic molecules, their energy. The structure of diatomic molecules and their interaction with light. Separation of electron and nuclear motion, Hamiltonian operator, Schrödinger equation, stationary energy and wave functions in adiabatic approximation. Full energy, its distribution in electron, oscillation and rotational energy. Rotation of diatomic molecules in classical and quantum approaches. Vibrational motion of diatomic molecules, its description. [1], [5].   1. **Electronic, vibration and rotation processes in diatomic molecules. Molecular states and spectra.**   Absorption and fluorescence processes in diatomic molecules. Electronic transitions in diatomic molecules. Matrix elements of dipole transitions in adiabatic approximation, separation of electronic, vibration and rotation factors. Selection rules for transitions in one electronic state and between different electronic states. Electron-vibration-rotation transitions. Frank-Condon principle, the difference potential. Observation of fluorescence progressions in the transition from the common excited level v ', J' to a range of ground state v ', J' levels. Discrete and continuous transitions and spectra. [1], [4], [5].   1. **Dynamics of molecular processes. Notion of vibrational wave-package and its evolution. Processes of atomic and molecular collisions, their studies by laser spectroscopy methods.**   Dynamics of molecular processes. The concept of the vibration wave package and its evolution. Atomic and molecular collision processes, their research by laser spectroscopy methods. The vibration wave package and its evolution in the molecular vibration process, the relationship between classical and quantum physics notions of vibrational motion. Real-time molecular vibrational motion. Dynamics of photodissociation and photoionization in the femtosecond range. [1].   1. **Chemical reactions, their classification. Reaction rate and rate constant. Collisional complex and coherent control of a chemical reaction.**   Chemical reactions and collision complex. The first and second order chemical reactions, the reaction rates. Photodissociation and recombination. Photoassociation: formation of cold molecules from cold atoms in MOT. Exothermic and endothermic reactions. Coherent control of chemical reaction, femtosecond laser pulse optimization scheme. It is recommended to consult the numerical examples from the relevant sections [1].   1. **Clusters, their formation and studies.**   Clusters as N-particle aggregates, their production. Examples: argon clusters, C60 (fullerene) cluster. Physical properties and analysis of clusters [1], [5]. | | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Biophotonics*** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 48 |
| ***Number of Seminar and Practical Assignment Hours*** | 8 |
| ***Number of Laboratory Work Hours*** | 8 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.habil.phys. Jānis Spīgulis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| Aim of this course is to provide knowledge and skills of independent work with regard to applications of optical methods in life sciences and biomedicine.  Tasks of the course are:  1. To get acquainted with basic concepts of tissue and plant optics;  2. To acquire the operation principles of biophotonics devices;  3. To gather information on clinical applications of optical methods;  4. To obtain practical skills in computer modelling of radiation propagation and in work with medical lasers.  Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains biophysics and Medical Physics relation to advanced optical methods and technologies; 2. Describes optoelectronic devices and methods possible applications in diagnostics, therapy and surgery; 3. Explains international standards of inter-disciplinary research;   Skills:   1. Performs laboratory excercises with medical lasers and other specific equipment; 2. Independently finds and analyzes the available in literature solutions and data on actual problems of the field in English; 3. Demonstrate communication skills presenting independently prepared topics in seminars of the course;   Competence:   1. Performs model calculations for biological systems, e.g. on propagation of optical radiation in living tissues by the Monte-Carlo method; 2. Evaluates suitability of physical equipment (e.g. laser devices, imaging devices, etc.) for specific clinical applications. | |
| ***Course Plan*** | |
| 1. Basics of the photonics: the main operational principles and significance of photonics; optical radiation sources; photo-detectors; image sensors; optical fibres and cables. L4 2. Fundamentals of tissue optics: absorption and scattering in soft tissues; light penetration in tissues, therapeutic window; optical parameters of various tissues; basic equations describing propagation of optical radfiation in tissues; Monte-Callo method; skin optics; eye optics. L6 3. Optical properties of plants: absorption and scattering in the plant structures; energy transfer in plants, photo-synthesis. L4 4. Seminar on optical properties of tissues and plants. S2 5. Ultraviolet radiation, its impact to life processes: origin and classification of UV radiation; peculiarities of Earth UV irradiation, significance of atmospheric ozone layer; skin erythema, tanning and other UV-irradiation effects; sunbeds and the exploited UV-sources, safety aspects. L4 6. Laser-tissue interactions: heating effects; photocoagulation of tissues; cell evaporation, photo-ablasion; laser-induced tissue craters; photo-peforators and laser scalpels; tissue photo-destruction by laser radiation. L4 7. Seminar on biological impacts of UV and laser irradiation. S2 8. Biofotonics equipment: Spectral devices and filters; microscopes; fluorometers; optical tomographs. L4 9. Medical lasers and their safe exploitation: main features of the medical lasers; types and classification of the medical lasers; laser safety in medicine. L6 10. Biophotonics methods in medicine. (i) Phototherapy: biostimulation; thermal phototherapy; photodynamic therapy (PDT), (ii) Laser surgery: coagulation, soldering and splicing; cutting of tissues; ablation; photo-disruption, (iii) Optical diagnostics: black-and-white, color and spectral imaging, parametric mapping; fluorescent methods; photo-bleaching; spectral methods including Raman spectroscopy; optical coherence tomography (OCT); diffuse optical tomography (DOT); Laser Doppler flowmetry (LDF) and speckle analysis, (iv) optical monitoring: photoplethysmography (PPG, PPGI); pulse oxymetry (PO); multi-spectral methods. L12 11. Laboratory excersises with optical diagnostics devices and medical lasers; defence and discussion of the results. Ld8 12. Defence of laboratory results, discussions. S4 13. Optical bio-sensors for environmental control: design and operation principles of bio-sensors; fiberoptical biosensors; spectral and similar biosensors; hyperspectral imaging systems; bio-lidars and other devices for remote monitoring. L4   L – lecture, S – seminar, P - practical work, Ld- laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students independently acquire knowledge from additional materials posted in the e-study environment along with each lecture material, they complete home excersises (e.g. Monte Carlo simulations of radiation propagation in tissues with self-selected parameters) and prepare presentations in seminars on the chosen topics, as well as independently are preparing to complete the tasks of laboratory excersises. | |
| ***Requirements for Awarding Credits*** | |
| Attendance of all lectures is desireable.  Intermediate tests:   1. Presentations (2) on the main topics in seminars - 30% 2. Laboratory exercises (2) - 30%   Final examination:   1. Exam (written) - 40% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | | 1. Home excersise –   MC-modelling | + | + |  |  |  |  | + |  | | 1. Presentation at the 1st seminar | + | + |  |  | + | + |  |  | | 1. Presentation at the 2nd seminar | + | + |  |  | + | + |  |  | | 1. 4 laboratory tasks | + | + | + | + |  |  |  | + | | 1. Exam | + | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Biomedical Photonics Handbook (ed. Tuan Vo-Dinh). CRT Press, 2003 2. Kohen, E., Santus, R., Hirshberg, J.G. Photobiology.Academic Press, San Diego, 1995.Online: http://www.ebook3000.com/Photobiology\_4646.html 3. Tuchin, V. Tissue Optics: Light Scattering Methods and Instruments for Medical Diagnostics. SPIE Press, Bellingham, 2007 4. Welsh, J., van Gemer, M. Optical Thermal Response of Laser-Irradiated Tissue, Plenum Press, N-Y, 2nd edition, 2011 | |
| ***Further Reading List*** | |
| 1. Handbook of Optical Biomedical Diagnostics (ed. V. Tuchin), SPIE Press, 2002 | |
| ***Periodicals and other sources*** | |
| 1. Biophotonics (USA) 2. Photonics Spectra (USA) | |
| ***Course Content*** |  |
| 1. Basics of photonics: main principles and significance. Optical radiation sources; photo-detectors; image sensors; optical fibers and cables. 2. Fundamentals of tissue optics: absorption and scattering in soft tissues; light penetration depth in tissues, the therapeutic window; optical parameters of various tissues; basic equations for description of radiation propagation in tissues; the Monte Carlo method; skin optics; eye optics. 3. Optical properties of plants: absorption and scattering in plant structures; energy transfer processes in plants; photosynthesis. 4. Ultraviolet radiation, its influence to living processes: origin and classification of UV radiation; specific features of Earth UV-irradiation, significance of the atmospheric ozone layer; skin erythema, tanning and other effects of UV-irradiation; solariums and their UV-sources, safety aspects. 5. Laser-tissue interactions: heating effects; photocoagulation of tissues; cell evaporation, photoablation; laser-induced tissue craters, photoprphorators and laser scalpels; laser photo-destruction of tissues. 6. Biophotonics equipment: spectral devices and filters; microscopes; fluorimeters; optical topographs. 7. Optical biosensors for environmental monitoring: design and principles of operation; optical fiber biosensors; spectral biosensors; systems of hyperspectral imaging; bio-lidars and other remote monitoring devices. 8. Medical lasers and their safe use: specific features of medical lasers, their types and classification; laser safety in healthcare. 9. Biophotonics methods in medicine. (i) Phototherapy; photo-biostimulation; thermal laser therapy; photodynamic therapy (PDT). (ii) Laser surgery: tissue laser coagulation, welding, cutting, ablation and disruption. (iii) Optical diagnostics: black-and-white, colour and spectral imaging, mapping of tissue parameters; fluorescence methods, photo-bleaching; spectral methods, including Raman spectroscopy; optical coherence tomography (OCT); diffuse optical tomography (DOT); laser-Doppler flowmetry (LDF) and speckle analysis. (iv) Optical monitoring: photoplethysmography (PPG, PPGI); pulse oximetry (PO); multi-spectral methods. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Laser physics II*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 30 |
| ***Number of Seminar and Practical Assignment Hours*** | 2 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Mg.phys. Artūrs Ciniņš |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of this course is to provide students with advanced knowledge and to guide to develop an understanding of laser operation principles and properties of laser radiation, and to provide insight into scientific laser applications.  Tasks of the course are to:   1. To introduce students to laser safety guidelines and to get acquainted with types of hazard posed by laser systems; 2. To develop an understanding of fundamental principles of laser operation; 3. To introduce properties of laser radiation and to develop understanding of the relevant physical processes; 4. To teach analysis of optical systems and calculating properties of laser cavities and laser radiation; 5. To introduce students with different types of lasers, their characteristic features and areas of application; 6. To introduce students to scientific laser applications.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains the principles of laser safety, the main risk factors for working with laser systems and the principles of selection and application of protective equipment; 2. Explains principles of theoretical description for light–matter interactions, the basics of macroscopic description, Einstein’s phenomenological microscopic theory and semiclassical theory of the light–matter interaction, the physical meaning and interrelationship of interaction characteristics arising from different theories; 3. Explains principles of generating coherent optical radiation; 4. Explains basic principles of optical systems analysis; 5. Explains basic principles of laser system design. Understands the principles of operation of the basic elements of a laser and their role in laser operation; 6. Names most significant types of lasers and their features; 7. Names properties and characteristics of laser radiation, as well as the basic principles of their measurement; 8. Describes the relation between the properties of laser radiation and laser structure, fundamental limits to laser radiation properties; 9. Explains typical applications of lasers and laser radiation in science and technology;   Skills:   1. Chooses appropriate protective equipment for work with laser systems and laser radiation; 2. Relates the parameters of a quantum system to macroscopic properties of a medium; 3. Calculates the effect of optical radiation on the level populations in quantum systems; 4. Uses data from spectroscopic data tables in calculating interactions between light and atomic media. Knows how to use Einstein coefficients to characterize light–matter interactions; 5. Calculates the necessary conditions for coherent amplification of radiation in an optically active medium; 6. Calculates the propagation properties of light in various optical elements and optical systems; 7. Performs analysis of optical cavities; 8. Calculates the necessary conditions for coherent generation of light in a laser; 9. Estimates and calculate properties of laser radiation, knowing characteristics of laser components;   Competence:   1. Is aware of potential hazards and able to assess risks when working with laser systems; 2. Evaluates the properties of optical systems; 3. Performs a simplified analysis of the light–matter interaction; 4. Recognizes the most common types of lasers and can assess the expected laser radiation properties; 5. In accordance with the set scientific objectives, evaluates the key parameters of laser light and laser systems necessary for the research. | |
| ***Course Plan*** | |
| 1. Fundamentals of light-matter interactions. Maxwell’s macroscopic theory. Einstein’s theory of light-matter interaction. Semiclassical description for interaction between quantum systems and light. L2 2. Principles of laser operation. Key elements of a laser. Light amplification and generation schemes L2 3. Mechanisms for supplying energy to a laser. Optical and electric pumping schemes. L2 4. Propagation of light. Fundamentals of geometrical optics. Fundamentals of Gaussian optics. L2 5. Types of laser resonators and their peculiarities. Resonator theory. Cavity modes. Cavity properties. L2 6. Properties of laser light. Coherence and beam divergence. Spectral composition of laser radiation. L2 7. Modes of laser operation. Multimode and single mode regimes. Cw and pulse generation. Q-switching and mode locking, ultrashort pulses. L2 8. Laser safety. Emission classes. Individual laser safety equipment and best practices for safe operation of laser systems. L2 9. Solid-state lasers. Common active media, typical pumping mechanisms, types of construction and properties of solid-state laser radiation. Ruby laser. Nd:YAG laser. Titanium-sapphire laser. L2 10. Gas lasers. Neutral atom gas lasers and ion lasers. He-Ne, Ar+, Cu lasers L2 11. Molecular gas lasers. CO2, N2, excimer lasers. L2 12. Tunable lasers. Dye lasers. L2 13. Semiconductor lasers. Principle of operation and design peculiarities. L2 14. Laser applications in chemistry, biology, material sciences etc. L2 15. Laser applications in physics – laser spectroscopy, nonlinear optics etc. L2 16. Seminar on laser applications in research. S2   L - lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Independent work of students is organized as individual work.  Tasks to be executed independently:   1. Prepare for lectures by studying the literature related to the course topics; 2. Solve homework problems on timely basis; 3. Choose a laser application that meets your professional interests and prepare for its presentation at the seminar. If any difficulty may arise in choosing the topic, you are encouraged to consult with the lecturer; 4. Prepare for the final exam. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Homework assignments – 50% 2. Talk at the seminar – 20%   Final examination:   1. Compulsory exam (oral) – 30%   Homework problems will be formulated during each lecture. Solutions to the problems must be submitted within 2 weeks after the assignment.  A seminar will be held near the end of semester for students to introduce audience to laser applications corresponding to their research interests. Subject of the talk must be coordinated with the lecturer no later than 2 weeks before the planned seminar date. The grade received for the talk can be improved by engaging in meaningful discussions during the seminar.  The compulsory final is an oral exam. During examination student must demonstrate sufficient knowledge and be able to engage in a short discussion on a subject drawn at random from the list of topics covered by this course. The list of topics will be available no later than two months before the end of semester. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **Examination type** | **Learning outcome** | | | | | | | | | | | | | | | | | | | | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | | 1. Homework assignments |  | + |  | + |  |  |  | + |  |  | + | + | + | + | + | + | + | + |  |  |  |  |  | | 1. Talk at the seminar | + |  |  |  |  |  |  |  | + | + |  |  |  |  |  |  |  |  | + |  |  |  | + | | 1. Final exam | + | + | + | + | + | + | + | + | + | + | + |  |  |  |  | + |  | + |  | + | + | + |  | | |
| ***Compulsory Reading List*** | |
| 1. Silfvast, W.T. Laser Fundamentals. Cambridge University Press, 1996 2. Svelto, O., Hanna, D.C. Principles of Lasers (4th edition). Plenum Press, 1998 | |
| ***Further Reading List*** | |
| 1. Loudon, R. The Quantum Theory of Light, 3rd ed. Oxford University Press, 2000. ISBN: 0198501773 2. Milloni, P.W., Eberly, J.H. Laser Physics. John Wiley & Sons, 2010. ISBN: 0470409703 3. Paschotta, R. RP Photonics Encyclopedia. Pieejms: <https://www.rp-photonics.com/encyclopedia.html> | |
| ***Periodicals and other sources*** | |
| Photonics Spectra magazine. Pieejams: <https://www.photonics.com/Photonics_Spectra> | |
| ***Course Content*** |  |
| **Fundamentals of light – matter interactions.**   1. Electromagnetic radiation and its interaction with a medium. Macroscopic parameters. Maxwell’s theory for electromagnetic field. 2. Einstein’s theory of light – matter interactions. Population rate-equations. Spontaneous and stimulated optical transitions in atoms. Nonradiative decay. Absorption and amplification of light. Population inversion. 3. Basics of semiclassical approach to quantum system and light interactions. Schrodinger’s equation and density matrix formalism.   **Principles of laser operation.**   1. Key elements of a laser. Laser classification based on active medium, cavity type and regime of operation. 2. Optically active medium. Schemes for light amplification and generation. 3. Supplying energy to the active medium. Optical and electric pumping schemes. 4. The role of optical feedback. Laser cavity (resonator). 5. Laser efficiency. Losses. Threshold condition for laser generation.   **Optical cavities.**   1. Light propagation in optical systems. Geometrical optics and ray transfer matrices. 2. Limitations of geometrical optics. Gaussian, Hermite-Gaussian and Laguerre-Gaussian beams. Gaussian optics. 3. Types of optical cavities and their properties, resonator theory. Resonator stability. 4. Cavity modes. Longitudinal modes. Fundamental modes and higher-order transverse modes. 5. Characteristics of a cavity. Free spectral range. Losses, finesse, and Q-factor.   **Laser radiation properties, modes of operation.**   1. Properties of a laser beam. Coherence time and coherence length. Angle of divergence, M2 factor and BPP. 2. Laser modes and their relation to cavity modes. Multimode and single mode operation. 3. Continuous-wave (cw) and laser pulse generation. Methods for obtaining laser pulses, and their typical applications. Q-switching. Mode locking. Ultrashort pulse generation, their properties and measurement techniques.   **Laser safety.**   1. Types of hazard. 2. Laser emission classes. 3. Protective glasses and other safety equipment. Best practices for safe laser operation.   **Types of lasers.**   1. Solid-state lasers. Common active media, typical pumping schemes, types of construction, and properties of solid-state laser radiation. Ruby laser. Nd:YAG laser. Titanium-sapphire laser. 2. Gas lasers. Common pumping mechanisms and typical characteristics of gas laser radiation. 3. Gas lasers. Neutral atom gas lasers, He-Ne laser. Metal vapor lasers, Cu laser. Ion lasers, Ar+ laser. 4. Molecular gas lasers. Vibrational-rotational lasers, CO2 laser. Vibronic lasers, N2 laser, excimer lasers. Rotational lasers. 5. Dye lasers – continuously tunable lasers. Principle of operation, design peculiarities. Key classes of organic dye molecules. 6. Semiconductor lasers. Principle of operation and design peculiarities.   **Laser applications.**   1. Laser applications in chemistry, biology, material sciences etc. 2. Laser applications in physics – laser spectroscopy, nonlinear optics etc. 3. Seminar on laser applications in research. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Contemporary Problems of Quantum Physics*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 16 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.habil.phys. Mārcis Auziņš |
| ***Prerequisite Knowledge*** | Fizi3088, Quantum Mechanics  Fizi4008, Quantum Physics |
| ***Study Course Abstract*** |  |
| The goal of the course is to analyze topics related to experimental studies carried out in recent years aimed at deepening the understanding of the foundations of quantum mechanics and addressing conceptual issues of quantum physics  The tasks of the course are:   1. to familiarize with the current challenges of modern quantum physics, which addrsses the conceptual issues of quantum physics; 2. to find out what conceptual quantum physics issues are currently being studied experimentally; 3. to gain understanding what concepts of quantum physics are currently considered interesting to deepen; 4. to be able to focus on the conceptual issues of modern quantum physics; 5. to focus on methods used to address the conceptual issues of modern quantum physics; 6. to be able to have a professional debate on the current challenges of modern quantum physics.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. describes of the scope of problems that are appearing in the current in quantum physics with a special emphasis on foundations of quantum physics; 2. explains the relationship between the problems of modern quantum physics and other subfields of modern physics, the general theory of relativity, cosmology;   Skills:   1. analyzes important modern quantum physics experiments, such as testing the EPR paradox, multi-particle interference experiments and similar; 2. assesses the reliability of experimental methods of modern quantum physics;   Competence:   1. discusses the basic conceptual issues of quantum physics; 2. assesses various statements on foundations of quantum physics. | |
| ***Course Plan*** | |
| 1. Eksperiments of contemporary quantum interference with relatively massive particles – fulerens and others. L2 S2 2. Multiparticle interference experiments – EPR paradox, Bell’s inequalities. L2 S2 3. Two-photon interference experiments from the aspect of particle angular coordinates and angular momentum. L2 S2 4. Two-photon interference experiments from the aspect of particle linear coordinates and impulses. L2 S2 5. Quantum measurements without interaction in Mach Cander type interferometer. L2 S2 6. Quantum tunneling effect and the speed of particle tunneling. L2 S2 7. Experimental tests of quantum complementarity. L2 S2 8. Hydrogen atom in a borderline case of classical physics. Kepler’s orbits in quantum mechanics. L2 S2   L – lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| For students, three original articles are offered for independent reading and analysis during semester. Student prepares a report on one of the course's topics during the semester. The report will be presented and discussed during the workshop (seminar). If time does not per0mit for all reports to be discussed during the workshops, it shall be prepared and submitted in writing. After submitting a written report, it is defended in a discussion with the instructor. | |
| ***Requirements for Awarding Credits*** | |
| Attendance of lectures - mandatory  Attendance of seminars – mandatory  Final mark consists of:  Intermediate test – 10%:  1.1. oral report in seminar on a topic of student’s choice  or  1.2. written review of scientific literature on a topic of student’s choice;  Final examination:  3. Exam (oral) – 10%  Discussion during seminair about topic of student’s choice or oral review of previous written review. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1.1. Report presented during the workshop | X | X | X | X |  |  | | 1.2. Report submitted in written | X | X | X | X |  |  | | 2. Exam |  |  | X | X | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Aharonov, Y. Rohrlich, D. Quantum paradoxes : quantum theory for the perplexed. Physics textbook. 2005, Weinheim: Wiley-VCH. x, 289 p. 2. Greenstein, G., Zajonc, A. The quantum challenge : modern research on the foundations of quantum mechanics. 2nd ed. 2006, Sudbury, Mass.: Jones and Bartlett Publishers. xviii, 300 p. 3. Scully, M.O., Zubairy, M.S. Quantum optics. 1997, Cambridge ; New York: Cambridge University Press. xxi, 630 p. 4. Žurnāls Physical Review A 5. Žurnāls Physical Review Letters 6. Žurnāls Reviews of Modern Physics | |
| ***Further Reading List*** | |
| 1. Elitzur, A.C., et al., Quo vadis quantum mechanics? Frontiers collection. 2005, Berlin ; New York: Springer. xiv, 421 p. 2. Gerry, C.C., Knight, P. Introductory quantum optics. 2005, Cambridge, UK ; New York: Cambridge University Press. xiii, 317 p 3. Paul, H., Introduction to quantum optics : from light quanta to quantum teleportation. 2004, Cambridge, UK ; New York: Cambridge University Press. xii, 241 p. 4. Suter, D., The physics of laser-atom interactions. Digitally printed 1st pbk. ed. 2005, Cambridge ; New York: Cambridge University Press. xiv, 457 p. | |
| ***Periodicals and other sources*** | |
| 1. Žurnāls Nature 2. Žurnāls Physics Today 3. Žurnāls Physics World 4. Žurnāls Science | |
| ***Course Content*** |  |
| 1. Modern quantum interference experiments with relatively massive particles – fullerenes and others.    1. Otto Stern experiments with helium atoms and hydrogen molecules.    2. Test of the characteristics of the Debroglie waves of atoms and molecules.    3. Anton Ceilinger's diffraction experiments in one slit and two-slit interference experiments with slow neutrons.    4. Anton Ceilinger's experiments with diffraction gratings and fullerenes. Decrease of interference pattern contrast with the increase of temperature of the fullerene. 2. Multi-particle interference experiments – EPR paradox, Bell inequalities    1. Derivation of the Bell’s inequalities.    2. Shimony-Holt inequalities for real experimental equipment and detectors with limited efficiency.    3. The original formulation of the Einstein Rosen Podolska (EPR) paradox. The modern formulation of the EPR paradox.    4. Test of Bell's inequalities in the Rarity and Tapster experiments. Testing of Bell’s inequalities in Allen Aspect’s experiments. A test of Bell's inequalities in Anton Ceilinger's experiments. 3. Two photon interference experiments from the point of view of the angular momentum of particles    1. Bell’s inequalities in the space of the angular momentum.    2. Experiments using particle spins and photons.    3. Thought experiments and real experiments. 4. Two photon interference experiments from the point of view of particle coordinates and linear moments    1. Bell’s inequalities in the space of the coordinates and momenta. Perfect experiment for testing of the Bell's inequalities in the coordinate and momentum space.    2. A real experiment for testing Bell's inequalities in the coordinate and momentum space, the practical implementation and outcome of the experiment. 5. Quantum measurements without interaction in the Mach Zehander interferometer    1. Non-interaction measurements in quantum physics.    2. Mach-Zehander interferometer and its functioning in the case of very weak light fluxes (single photons). Difference of optical paths between two interferometer channels.    3. The methods to increase the efficiency of detection of an object without interaction.    4. The quantum Zeno effect. Getting an whole image without interaction. Paul Kwiat experiments. 6. Quantum tunnelling dynamics and tunnelling rate.    1. Tunnelling probability in quantum physics. Tunnelling dynamics, tunnelling speed.    2. Tunnelling speed measurements in Chao experiments. Time operator in quantum physics.    3. Interpretation of tunnelling rate and speed which can occur to be faster than light.    4. Computer models for tunnelling dynamics. 7. The experimental quantum complementarity tests    1. Uncertainty and entanglements in quantum mechanics.    2. Experiments allowing the determination of particle trajectory elements without affecting particles quantum state.    3. An ideal experiment for which way experiment and practical realisation of the idea. Quantum eraser. How to erase quantum information after obtaining it. 8. A hydrogen atom in the transition from quantum to classical physics, the quantum mechanics of Kepler's orbit.    1. Classical dynamics of particle on the orbit and quantum dynamics    2. Solutions of the Schrodinger equation. Superpositional states and wave packets in quantum mechanics.    3. Harmonic oscillator, quantum mechanical description and classical description of its dynamics. Harmonic oscillator and its description with wave packets. Kepler’s orbits for a hydrogen atom and wave packets. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Quantum optics*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 32 |
| ***Number of Seminar and Practical Assignment Hours*** | 0 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 04.03.2021 |
| ***Course Developer*** | Dr.habil.phys. Mārcis Auziņš |
| ***Prerequisite Knowledge*** | Fizi4008, Quantum Physics |
| ***Study Course Abstract*** |  |
| The aim of the course is using a quantum mechanical and quasi-classical description method analyze the interaction between light and substance (mostly atoms).  The tasks of the course are:   1. to familiarize with key concepts of quantum optics; 2. to find out the main stages of development of quantum optics; 3. to understand the relationship of quantum optics with branches of classical physics — quantum physics, optics, classical mechanics, electricity and others; 4. to learn to solve the simplest quantum optics problems; 5. to know the main methods used in quantum optics; 6. to gain an ability to choose the right method to solve particular problems of quantum optics; 7. to be competent to assess potential technological applications of quantum optics.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains the main concepts of quantum optics; 2. Understands the main stages of development of quantum optics; 3. Describes the relationship of quantum optics to subfields of classical physics: quantum physics, optics, classical mechanics, electricity and others;   Skills:   1. Solves the simple quantum optics problems IN; 2. Assesses techniques used in quantum optics;   Competence:   1. Selects description methods corresponding to the specific problem of quantum optics; 2. Assesses potential technological applications of quantum optics in V3. | |
| ***Course Plan*** | |
| 1. Introduction. L1 2. Two-level atom. L1 3. The Quantum density matrix and Bloach equation. L2 4. Bloha vectors and interferometry in quantum optics. L2 5. Quantified fields. L2 6. Classically and non-classical states of light. L2 7. Quantum fields and interference experiments. L2 8. Quantum field interaction with matter. L2 9. Quantum optics of one mode. L2   L - lecture | |
| ***Characterization of students' independent work organization and tasks*** | |
| During the semester, six (in average once in two weeks) homework with a specified deadline for submission is required. The intermediate test is organized in the middle of the semester and an written exam is organised at the end of course. | |
| ***Requirements for Awarding Credits*** | |
| Lecture attendance – mandatory.  Intermediate tests:   1. Homework - 40% 2. Mid-term test - 20%   Final examination:   1. Exam (written) - 40% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1. Homework |  |  |  | X | X | X |  | | 1. Midterm test | X | X | X |  |  |  |  | | 1. Written exam | X | X | X | X | X | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Gerry, Ch., Knight, P., Introductory Quantum Optics, (Cambridge University Press 2006) Very well structured introduction into Quantum Optics 2. Loudon, R., The Quantum Theory of Light ,(Oxford University Press), Classic Quantum Optics textbook, one of the best introductory books, but lacks discussion of modern experiments 3. Scully, MO., Suhail Zubairy, M. Quantum Optics (Cambridge University Press), Advanced book on Quantum Optics, Modern Notation | |
| ***Further Reading List*** | |
| 1. Haroche, S., Raimond, J.M., Exploring the quantum, (Oxford University Press 2006), Focus on Cavity-QED, Good discussion of fundamental quantum effects (Entanglement, Non-Locality, Decoherence, Measurement Process, Quantum Information Processing) 2. Fox, M., Quantum Optics, (Oxford University Press), Good elementary introduction 3. Cohen-Tannoudji, C., Dupont-Roc, J., Grynberg, G. Atom Photon Interactions , (Wiley 4. Interscience), Focus on Light Atom Interaction, very detailed and authoritative discussion, advanced level | |
| ***Periodicals and other sources*** | |
| 1. Nature Physics 2. Nature Photonics 3. Reviews of Modern Physics | |
| ***Course Content*** |  |
| **1. Introduction.**  1.1 Models of light – atom interaction in classical physics, quasi-classical approximation and models of light – atom interaction in quantum physics.  1.2 Charged particles and electromagnetic field interaction Hamiltonian  1.3 Time-dependent perturbation theory in quantum physics  1.4 Amplitude, probability and rete of quantum transitions  1.5 Fermi’s golden law  **2. Two-level atom**  2.1 Two-level atom, Schrodinger approach  2.1 Atom as a dipole oscillator  2.2 Bloch sphere as a tool for the description of quantum states and their dynamics  **3. Quantum density matrix, Liouville Equation and Optical Bloch Equations**  3.1 Density operator in quantum physics and density matrix  3.2 Optical Bloch equations. Stationary states in quantum physics and their evolution  3.3 Rabi frequency, saturation of quantum transition, spontaneous decay of the atom. Lamb shift.  3.4 Spectral line-shape in fluorescence, saturation broadening.  **4. Bloch vectors and interferometry in quantum optics**  4.1 Bloch vector  4.2 Ramzi method in quantum optics  4.3 Mach Zehander interferometer in quantum optics.  **5. Quantized fields**  5.1 Quantized radiation modes  5.2 Harmonic oscillator in quantum mechanics  5.3 Rising and lowering operators. Number operator  **6. Classical and non-classical states of light**  6.1 Fock states  6.2 Coherent states  6.3 Equilibrium states and squeezed states  6.4 Plank’s black body radiation  **7. Quantum fields and interference experiments**  7.1 Beam splitters in classical physics and quantum optics  7.2 Mach Zehander interferometer in quantum optics  **8. Quantum field interaction with matter**  8.1 Interaction of quantized light with atoms  8.2 Interaction hamiltonian  8.3 Jaynes–Cummings Hamiltonian  8.4 Quantum Rabi oscillation  8.5 Vacuum Rabi oscillation  **9. Quantum optics of one mode**  9.1 Cavity quantum electrodynamics  9.2 Optical resonators  9.3 Microwave resonators and atoms in the Rydberg states  9.4 Weak interaction in atomic physics  9.5 Rabi oscillation in case of dressed states | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | **Open System Physics** |
|  | Physics and astronomy |
| ***Credits*** | *2* |
| ***Total Number of Contact Hours*** | *32* |
| ***Number of Lecture Hours*** | 16 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** |  |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 09.02.2021 |
| ***Course Developer*** | Dr. Paed, Lolita Jonāne |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to promote the development of students' knowledge and understanding of modern science development trends, the transdisciplinary nature and complementarity of natural science development.  Tasks of the course are:   1. to acquaint with the basic concepts of systems theory, research methods and principles; 2. to analyze examples of different (mechanical, thermodynamic, chemical, biological) systems, and fractal structures, and theories for modeling nonlinear dynamic systems; 3. to introduce with the essence of synergy in the perspective of 21st century scientific development.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Characterizes the principles of behavior of different (mechanical, thermodynamic, chemical, biological) systems; 2. Understands, explains and illustrates by concepts the laws and laws of open systems physics; 3. Describes the essence of chaos theory and its application in modeling the development of dynamic systems; 4. Explains the nature of self-organization in natural and social systems;   Skills:   1. Obtains, analyzes and presents information on the behavior of various non-linear mechanical, thermodynamic, biological and social systems;   Competence:   1. Analyzes common regularities in the dynamics of different systems; 2. Evaluates and makes responsible and fact-based decisions about the context of their activities. | |
| ***Course Plan*** | |
| 1. Introduction to Synergy. Description of systems. Development of thermodynamics. L4 S2 2. Determinism. Determined chaos. L2 S2 3. Attractors. Modeling of Nonlinear Dynamic Systems L2 S2 4. Fractal structures.L2 S2 5. Self-organization in fluids and processes in biological systems L4 S4 6. The paradigms of synergy. Self-organization L2 S4   L – lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is planned after each lecture and is related to the introduced topic.  Independent work is organized individually in preparation for seminars and mid-term examinations.  Independent tasks:   1. Regularly read and analyze scientific sources and report on seminar topics. 2. Prepare 2 presentations on a specific topic while studying relevant scientific literature. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Systematic and independent analysis of scientific literature, while preparing for seminars - 20% 2. Preparation and presentation of two presentations - 40%   Final examination:   1. Exam (written) - 40%   The final evaluation of the study course acquisition is formed by summing up the results during the whole study course acquisition. Students may take the final exam if two presentations have been made. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1.Intermediate examination. Presentation | + | + |  |  | + |  |  | | 2. Intermediate examination. Presentation | + | + | + | + | + | + |  | | 3. Exam | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Lectures on fractal and dimension theory, <https://homepages.warwick.ac.uk/~masdbl/dimension-total.pdf> 2. Synergetics, H.G., An Introduction Nonequilibrium Phase Transitions and Self-Organization in Physics, Chemistry, and Biology. Berlin, New York Tokyo 1983 Pieejams: <http://norlx51.nordita.org/~brandenb/AstroDyn/progress/material/Haken83.pdf> 3. Theilen, E., Smith, L. Dynamic Systems Theories Pieejams: <http://www.iub.edu/~cogdev/labwork/handbook.pdf> | |
|  | |
| 1. Bula, I. Haoss. Lekciju konspekts pieejams: <http://home.lu.lv/~ibula/lv/studentiem/haviss2.pdf> 2. Günther,F. Self-Organisation in Systems far from Thermodynamic Equilibrium: Some Clues to the Structure and Function of Biological Systems Pieejams: <https://www.holon.se/folke/written/stuff/lic/LICKAPPA.pdf> 3. Heylighen, F. The science of self-organization and adaptivity Pieejams: <http://pespmc1.vub.ac.be/Papers/EOLSS-Self-Organiz.pdf> 4. Siliņš, E. I.. Lielo patiesību meklējumi. Jumava. 1999, 510 7.П. | |
| ***Periodicals and other sources*** | |
| 1. Fractal Foundation, https://fractalfoundation.org | |
| ***Course Content*** |  |
| 1. Introduction. Characterization of the system . Chaos and order in thermodynamic systems. 2. Three stages of thermodynamic development. Entropy and irreversibility of processes. Introduction to Synergetics. Evolution. Self-organization.   Seminar. What is Synergy? Contribution of G. Hacken and I. Prigozhin to the development of synergy.   1. Determinism. Classic mechanical nonlinear systems. The problem of the three-body task of Puncaque. Stability. Attractors. Concept of phase space, system phase portrait.   Seminar. Determined chaos. Analysis of behavioral models of mathematical systems and mathematical models.   1. Behavioral modeling of nonlinear dynamic systems. Lawrence attractor. Butterfly effect. Logistic function. Iterations. Chaos theory. The concept of bifurcations. Hopf bifurcation. Bifurcation cascades.   Seminar. Analysis of literature sources on examples of attractors (Ikeda attractor, Chua attractor) and bifurcations in physical, biological and social systems.   1. Fractal structures in nature. Determined fractals. The Hausdorff dimension. Mandelbrot Set.   Seminar. Analysis of information from literature on examples of fractal structures and their application in technology development.   1. Self-organization in liquids. Thermal convection. Benard effect. Lizeganga structures. Dynamics and Bistability of Nonlinear Chemical Systems. Belousova\_Jabotinska reaction. Seminar. Chemical fluctuations. Formation of Thuringian structures. Formation of spatial structures and waves on the surface of catalysts. 2. Evolutionary processes in biological systems. Loss of bifurcation and symmetry. Hilary molecules. Biomolecular asymmetry.   Seminar. Synthetics in biological systems. Research of biochemical physics. Self-reproduction, formation of clusters. Competition and selection. Competition between clusters.   1. Synergetic paradigms. Self-organization.   Semimar. Self-organization in social systems. Network systems. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | **Didactics of Natural Science** |
|  | Physics and astronomy / Education |
| ***Credits*** | *2* |
| ***Total Number of Contact Hours*** | *32* |
| ***Number of Lecture Hours*** | 16 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** |  |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 09.02.2021 |
| ***Course Developer*** | Dr.paed. Lolita Jonāne |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to promote the development of students' knowledge and competencies for pedagogical work in educational institutions.  Tasks of the course are:   1. to help build an understanding about educational normative documents, principles of planning and organization of physics / natural sciences study process; 2. to analyze didactic theories, approaches, teaching methods and resources in the organization of physics/ science education by participating in lectures and seminars and independently studying scientific literature and methodological materials; 3. to practice planning and analyzing approaches, methods and techniques for achieving specific results, developing creative and critical thinking and understanding of the ways of assessing learners' outcomes and their implementation.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** | |
| Knowledge:   1. Describes didactic categories, didactic theories and didactic approaches in education; 2. Is aware of need for professional development and is able to implement it;   Skills:   1. Sets learning goals and formulate learning outcomes; 2. Analyzes and plans learning activities: lessons, development of research papers, choosing appropriate teaching models and methods; 3. Applicates various methods and methods for assessing student performance;   Competence:   1. Analyzes, plans the learning process in physics according to the learning goal and the planned result, taking into account the learning styles and mental abilities of the students; 2. Implements assessment of results, justifies its purpose and role in the learning process; 3. Makes responsible and fact-based decisions about developing one's professional competence. | |
| ***Course Plan*** | |
| 1. Conceptual frameworks for science education. L2 2. The study process and the theoretical basis of its organization. L4 S6 3. Planning of Physics Learning Process.L2 S2 4. Teaching methods and teaching forms L6 S6 5. Types, forms and methods of assessment. L2 S2   L – lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is planned after each lecture and is related to the spectroscopic method introduced in the lecture. While studying the lecture materials, students perform the test. Independent work is organized individually in preparation for seminars and mid-term examinations. Independent tasks:  Students' independent work is planned after each lecture, it is related to the topic introduced in the lesson. Independent work is organized individually and in groups, preparing for seminars and mid-term examinations. Final examination is the presentation of the work portfolio created during the study course (analysis of the literature relevant to the content of the study course, independent work).  Independent tasks:   1. To read and analyze scientific sources and to review the conceptual frameworks of science education, didactic theories, learning styles and approaches. 2. Obtain and compile information on a transdisciplinary approach to science education. 3. Analyze scientific sources and methodological materials and make an overview of the forms, methods and methods of teaching. 4. Develop a lesson plan using a problem solving or research approach. 5. Analyze scientific sources and methodological materials and make an overview of teaching/ learning methods. 6. Develop a final paper test in physics on a selected topic. 7. Evaluate one's competences in science didactics by writing an argumentative essay. | |
| ***Requirements for Awarding Credits*** | |
| Active participation in lectures and seminars.  Systematic and independent analysis of scientific literature, while preparing for seminars and carrying out independent work.  Intermediate exams:   1. Intermediate Test 1. Lesson plan with problem solving / research approach - 30% 2. Intermediate Test 2. Thesis completion - 20%   Final examination:   1. Exam (combined) – 50 %   1) presentation of a portfolio of science teaching methods; 2) self-assessment of their competence in science teaching, writing and presenting a reasoned essay and taking part in a discussion on any of the course content. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment |  | | Learning outcomes | | | | | | | | 1. | 2. | | 3. | 4. | 5. | 6. | 7. | 8. | | 1.Intermediate examination. Lesson plan. | + |  | | + | + | + | + |  | + | | 2. Intermediate examination. Creating test. | + |  | | + |  |  | + | + |  | | 3.Exam | + | + | | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Marinko, I., Marinko, J. at all. Empowering teachers for a student centred approach ERASMUS+ 2015 Pieejams: <https://wsh.pl/wp-content/uploads/2015/05/empowering-teachers-for-a-student-centred-approach.pdf> | |
| ***Further Reading List*** | |
| 1. Broks, A., Izglītības sistemoloģija. –R.: RaKa, 2001. 2. Gambier, Y., Yliopisto, T., Teacher-centered and student-centered pedagogy 3. Koaik, Z. Teacher-centered and student-centered pedagogy Pieejams: <https://www.academia.edu/37819640/Teacher-centered_and_student-centered_pedagogy> 4. Projekta „Mācību satura izstrāde un skolotāju tālākizglītība dabaszinātņu, matemātikas un tehnoloģiju priekšmetos” materiāli, ISEC, Rīga, 2008. Metodiskie materiāli pieejami: <http://www.dzm.lu.lv/pedagogiem/metodiskie_materiali> 5. Scientific Inquiry and Nature of Science : Contemporary Trends and Issues in Science Education / edited by L. B. Flick, N. G. Lederman. - Dordrecht : Springer, 2006. 6. Transdisciplinary Teaching and Learning Pieejams: <https://www.academia.edu/33776740/Transdisciplinary_Teaching_and_Learning> | |
| ***Periodicals and other sources*** | |
| 1. Electronic Journal of Science Education. https://ejse.southwestern.edu/ 2. Izglītības un zinātnes ministrijas mājas lapa: [www.izm.gov.lv](http://www.izm.gov.lv) 3. Journal of Baltic Science Education <http://www.scientiasocialis.lt/jbse/> 4. Journal of Teacher Education for Sustainability, <http://ise-lv.eu/publications.php?show=39> 5. Phet. Interactive Simulations: <https://phet.colorado.edu/en/simulations/category/physics> 6. Projekta skola 2030 materiāli. Pieejami: [www.skola2030.lv](http://www.skola2030.lv/) | |
| ***Course Content*** | |
| 1. Introduction. Conceptual Framework for Science Education. Methodology of natural sciences. The aims, content and tasks of the didactics of natural sciences. Knowledge system in natural sciences. 2. The study process and the theoretical basis of it’s organization. Didactics. Learning theories. 3. Constructive, contextual and transdisciplinary approach to the organization of science education. Inductive and deductive approach. 4. Seminar. Learning theories (Vigotsky theory of zones, Ganier theory). Analysis, critical evaluation of information from literary sources. 5. Seminar. Learning styles.Different nature of knowledge and skills to be acquired and differences in their acquisition. 6. Planning of the Study Process. Learning outcomes. Lesson structure and effectiveness.   3. Seminar. Learning process planning Taxonomy of learning goals.  4. Seminar. A transdisciplinary approach to science education. A complex result to be achieved. Analysis and evaluation of lesson plans. Analysis and critical evaluation of information from literary sources.   1. Forms and methods of teaching physics / science. Types and Levels of Cognitive Activity Learning Objectives in the Cognitive Field (Bloom Taxonomy). Solo taxonomy. 2. Problem solving and research in natural sciences. Development and evaluation of research skills. Seminar. Problem solving and research in natural sciences. Presentations and discussion on information from literary sources, its critical evaluation.   Intermediate test. Elaboration / analysis of the lesson plan, using problem solving approach.  7. Practical and research methods in physics / science teaching. Research laboratory works, methodology of their organization for the development of research skills. Learning models.  6. Seminar. Practical and research methods in science teaching. Observation, experiment, demonstration methodology. Laboratory works, research laboratory works, methodology of their organization for the development of research skills. Use of data acquisition, processing. Learning models, their usage.  8. Verbal teaching/learning methods in science teaching. Methodology of concept acquisition. Multiple questions. Work with text. Argumentation. Visualization and presentation.  7. Seminar. Verbal teaching methods. Multiple issues. Strategies for organizing work wit text. Critical thinking. Typical and problem solving. Directed learning. A critical evaluation of the findings of the literature.  8. Seminar. Formative and summative assessment. Test tasks - measuring instruments for measuring the results to be achieved; their creation and selection. Analysis and evaluation of tests.  Intermediate test. Elaboration of the final thesis of the topic and development of a formative assessment that corresponds to the specific outcomes to be achieved by the learners. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | **Electron Microscopy** |
|  | Physics and astronomy |
| ***Credits*** | *2* |
| ***Total Number of Contact Hours*** | *32* |
| ***Number of Lecture Hours*** | 8 |
| ***Number of Seminar and Practical Assignment Hours*** |  |
| ***Number of Laboratory Work Hours*** | 24 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 09.02.2021 |
| ***Course Developer*** | Dr. phys. Edmunds Tamanis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| Aim of the course is to promote the development of students' knowledge and competencies about the basic principles of electron microscopy, to acquire practical skills of working with scanning electron microscope.  Tasks of the study course are:   1. to learn the basic principles of electron microscopy; 2. to acquire practical skills for working with a scanning electron microscope; 3. to master the basic principles of sample preparation for work with SEM; 4. to learn the basic principles of SEM maintenance.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands the latest developments in electron microscopy; 2. Understands the principles of operation of various electron microscopes and is aware of their potential;   Skills:   1. Masters electron microscopy research methods; 2. Uses DU SEM equipment; 3. Prepares samples;   Competence:   1. Performs independent and critical analysis of the obtained electron microscopy data, to draw important conclusions for the research; 2. Independently evaluates and selects electron microscopy methods appropriate for the research; 3. Independently learns the latest electron microscopy methods and applies them in research work. | |
| ***Course Plan*** | |
| 1. Principles of electron microscopy, nature of electron waves; Construction of electron microscopes: transmission microscopes, detectors; Construction of electron microscopes: scanning microscopes, detectors. L6 2. SEM - Power On, Set Up, Resolution Test; Sample preparation, non-conducting samples, biological samples; Basic works: magnification, working distance, beam diameter adjustment; Beam centering; Astigmatism Prevention. Ld10 3. ESD and EDX - Operating principle; Microanalysis, calibration; Microanalysis, data processing. L2 Ld4 4. SEM - Reflected Electron Diffraction, Data Processing and Analysis. Ld4 5. SEM - filament change, beam adjustment after filament change. Ld4 6. SEM – Maintenance. Ld2   L – lecture, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is planned after each lecture and is related to the topic.  Student work is organized individually and in groups, independently preparing for laboratory work.  Independent work tasks:   1. Independent acquaintance with the theory corresponding to a specific laboratory work; 2. Studying relevant scientific literature. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate test:   1. development of practical / laboratory works - 80%.   Final examination:   1. Exam (oral) - 20%   The final evaluation of the study course consists of the evaluation of the laboratory work and the exam. Students develop laboratory work during lessons. Students take the exam only if all laboratory works have been developed and defended. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assesment | Learning outcomes | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | | 1. Intermediate test: laboratory work |  |  | + | + | + | + |  |  | | 2. Intermediate test: laboratory work |  | + | + | + | + | + |  |  | | 3. Exam (oral) | + | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Dunlap, R. A. Experimental Physics : Modern Methods. Oxford University Press, 1988. 2. Flegler, L.S. Scanning and Transmission Electron Microscopy : An Introduction. Oxford University Press, 1995. | |
| ***Further Reading List*** | |
| 1. Davies, P. (Ed.). The New Physics. London : Cambridge University Press, 1993, | |
| ***Periodicals and other sources*** | |
| 1. Okabe, S. (Editor-in-Chief) Microscopy. | |
| ***Course Content*** |  |
|  | |

1. Principles of electron microscopy, nature of electron waves;

Discovery of the nature of electron waves, DeBrolley&#39;s theory, Davisson-Germer experiment, electron diffraction, its wavelength and energy

1. Structure of electron microscopes, source of electrons, their types. Principles of electron beam

control. Principle of transmission electron microscope operation, types of detectors used.

1. Scanning electron microscopes, used detectors - reflected electron detector, secondary electron

detector, operating features.

1. Laboratory works: SEM - power on, preparation, resolution test; Sample preparation, non-conducting samples, biological samples; Basic works: magnification, working distance, beam diameter adjustment;

Beam centering; Prevention of astigmatism

1. Basics of microanalysis of materials, principles of hard and soft X-ray generation, principles of

X-ray spectrometry. Basics of energy dispersive X-ray spectrometry, EDS detector, principles of operation.Basic principles of electron backscattering diffraction, requirements for sample

preparation, basics of data processing.

1. Basics of electron microscopy sample preparation, preparation of biological samples.

Laboratory works: ESD and EDX - principle of operation; Microanalysis, calibration;

Microanalysis, data processing; SEM - reflected electron diffraction, data processing and analysis; SEM - filament change, beam adjustment after filament change; SEM - Maintenance.

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | **Introduction to sensor technology** |
|  | Physics and astronomy |
| ***Credits*** | *4* |
| ***Total Number of Contact Hours*** | *64* |
| ***Number of Lecture Hours*** | 32 |
| ***Number of Seminar and Practical Assignment Hours*** | 32 |
| ***Number of Laboratory Work Hours*** |  |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 09.02.2021 |
| ***Course Developer*** | Dr. phys. Irēna Mihailova,  Dr. phys. Marina Krasovska |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of course is to develop a systematic knowledge and understanding of the various types of sensors and devices that provide objective information about the world around us and the physical processes by which this information is extracted.  Tasks of the course are:   1. to acquire the key concepts about sensors and intelligent systems and their classification; 2. to learn and research different types of mechanical, acoustic, electrical, electromagnetic, electrochemical and optical, simple and smart sensors as well as gain greater understanding of the physical principles of their operation; 3. to analyse approaches for smart sensors development and gives practical recommendations for their software development; 4. to learn the principles of construction and main technical characteristics of their main structural units; 5. to assess the directions of further development of intelligent systems; 6. to develop practical skills in experiment design, electrochemical sensor design and electrochemical measurements; 7. to gain analysis skills, critical thinking, and scientific literacy.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Describes the types of sensors and smart systems and their fields of application; 2. Understands the physical principles of operation of sensors and intelligent sensor-actuator systems;   Skills:   1. Analyzes and explains the operating principles of sensors and intelligent systems, using relevant concepts, models and theories; 2. Creates a prototype of electrochemical sensor and test its function; 3. Acquires, analyzes and critically evaluates information from various sources about different types of sensors and their applications;   Competence:   1. Independently analyzes the latest research in sensor and intelligent systems research; 2. Evaluates the use of intelligent systems in automation and manufacturing. | |
| ***Course Plan*** | |
| 1. Introduction: from simple sensors to intelligent systems. Sensor materials and signal processing technologies. L2 2. Types of mechanical sensors. L4 S2 P2 3. Acoustic sensors. L2 S2 P2 4. Physical basis of electric sensors operation, their classification. L4 S2 P2 5. Electromagnetic sensors. SQUID sensors. Inductive sensors.L4 S2 P2 6. Types of electrochemical sensors and their working principles. Smart electrochemical sensors. L6 S2 P8 7. Optical sensors. L6 S2 8. Design and programming of smart sensors. Nanotechnology-based Sensors: Opportunities, Realities and Applications. Prospects for the development of smart sensors. L2 S2 9. Multisensor systems: smart nose, smart tongue, lab-on-chip. L2 S2   L – lecture, S – seminar, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| The students' individual work is intended after each lecture in order to better understand the topic learned during the lesson and to prepare for seminars and mid-term examinations.  Independent tasks:   1. To read and analyze scientific literature and to report on the development of sensor and signal processing technologies and today’s challenges. 2. Obtain, analyze, and collect information on the design and function of a particular sensor type / smart system:    1. accelerometers and gyros, vibration and chromatographic sensors,    2. active acoustic sensors,    3. digital and video camera, thermal imaging and dactyloscopic sensors,    4. radio, radar and radio-television sensors,    5. biosensors,    6. smart electrochemical sensors,    7. diffuse reflectance spectroscopy sensor;    8. Surface Plasmon Resonance (SPR) sensors and fiber optic sensors;    9. multisensor systems.   3. Analyze scientific literature and prepare a presentation on the latest research in the development of intelligent systems. | |
| ***Requirements for Awarding Credits*** | |
| Active participation in lectures, seminars and practical works.  Systematic, independent analysis of the indicated methodological and study literature, which is reflected in independent works (tasks).  Intermediate tests:   1. Intermediate Test 1. Development of electrochemical sensor - 20% 2. Intermediate Test 2. Test on sensor types, intelligent systems - 20% 3. Intermediate Test 3. Presentation of the latest research in intelligent systems research / development - 20%   Final examination:   1. Exam - presentation of one study course question, discussion and argumentation about one of the types of sensors, explanation of its working principles - 40%   The final grade is determined by a weighted average score for all individual assignments (independent work) and the examination. Students submit their individual work by the dates specified in the lesson plan. Students take the exam only if all intermediate examinations have been passed. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1. Development of electrochemical sensor | + | + | + | + |  |  | + | | 2. Test on sensor types, intelligent systems | + | + | + |  |  |  |  | | 3. Presentation of the latest research in intelligent systems research / development | + | + |  | + | + | + | + | | 4. Final examination (exam) | + | + | + |  | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Cornelius, T. MEMS/NEMS: Vol. 4. Sensors and actuators. Leondes. Springer, 2006 - Microelectromechanical systems 2. Fraden, J.(3rd ed.) Handbook of modern sensors: physics, designs, and applications / Springer, 2004 3. Nyce, D.S. Linear position sensors: theory and application. Wiley Interscience, 2004. E-grāmata pieejama: <http://www.kelm.ftn.uns.ac.rs/literatura/si/pdf/LinearPositionSensors.pdf> 4. Zribi, A., Fortin, J. (ed.) Functional thin films and nanostructures for senors : synthesis, physics and applications / [Springer](https://biblio.du.lv/Alise/lv/advancedsearch.aspx?crit0=publ&op0=%25LIKE%25&val0=Springer&bop1=AND&crit1=auth&op1=%3D&val1=) 2008 | |
| ***Further Reading List*** | |
| 1. Science Direct, <https://www.sciencedirect.com/> | |
| ***Periodicals and other sources*** | |
| 1. Sensor Solutions Magazine, <https://sensorsolutions.net/home> 2. Sensor Technology Magazine Articles, <https://www.sensors.co.uk/media-centre/magazine-articles/> 3. Sensor Technology Magazine, <https://www.techbriefsmediagroup.com/magazines/sensor-technology> | |
| ***Course Content*** |  |
|  | |

1. Introduction. From simple sensors to smart systems. Sensor materials and signal processing technologies. Methods and principles of measuring physical quantities.
2. Types of mechanical sensors. Microsystems technologies. Deformation sensors. Mechanical motion sensors. Global navigation system operating principles and GPS sensors.
3. Seminar. Accelerometers and gyros. Vibration and chromatographic sensors.
4. Practical work. Motion sensors. Wireless power sensors. Accelerometer. Rotation sensors.
5. Physical basics of acoustic sensor operation. Acoustic signal receivers. Smart acoustic sensors.
6. Seminar. Active acoustic sensors: tonometers, echolocators and hydrolocators. Sensors for seismic research.
7. Practical work. Sound sensors.
8. The physical basis of the operation of electrical sensors, their classification. Resistive, capacitive and impedance sensors.
9. Voltamperometric sensors. Sensors based on diodes and bipolar transistors. Sensors based on field effect transistors and devices with negative I–V curve. Discharge sensors.
10. Seminar. Digital cameras and camcorders, thermal imaging, dactyloscopic sensors.
11. Practical work. Pressure sensors. Temperature sensors. Heat sensors.
12. Electromagnetic sensors. SQUID sensors. Inductive sensors, their operation and application.
13. Practical work. Magnetic field sensors.
14. Seminar. Radiosensors and radar. Radio-television sensors.
15. Principles of operation of electrochemical sensors. Potentiometric sensors. Conductometric and amperometric sensors. Voltammetric and chronoamperometric sensors.
16. Seminar. Biosensor. Smart electrochemical sensors.
17. Practical work. Development of an electrochemical sensor for detection of heavy metal ions or glucose in aqueous solutions. Performing electrochemical measurements.
18. Optical sensors. Spectrophotometric sensors. Photoplethysmographs. Oximeters and medical pulse oximeters. Diffuse reflectance spectroscopy sensors.
19. Basic principles of luminescence sensors. Chronofluorometer. Sensors with fluorescent markers. Bioluminescent and scintillation sensors. Principles of SPR sensors. Industrial SPR sensors.
20. Seminar. Sensors based on diffuse reflectance spectroscopy. Hemoglobinomers and Blood Fill Sensors. Non-invasive glycometers. Spectrophotometric chlorophyll sensors.
21. Seminar. SPR immune sensors and fiber optic sensors. Removable receptor chips.
22. Smart sensor design and programming. Selecting useful signals. Nanotechnology-based Sensors: Opportunities, Reality and Applications.
23. Seminar. Prospects for the development of smart sensors.
24. Multi-sensor systems: smart nose, smart tongue, lab-on-chip.
25. Seminar. Future perspectives of multisensor systems.

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

|  |  |
| --- | --- |
| ***Study Course Title*** | **Nanomaterial production technologies** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 32 |
| ***Number of Seminar and Practical Assignment Hours*** | 32 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 09.02.2021 |
| ***Course Developer*** | Dr. phys. Marina Krasovska,  Dr. phys. Edmunds Tamanis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to increase the knowledge level and competencies of undergraduates for planning and further research in the field of nanotechnology.  The tasks of the course are:   1. to get acquainted with the technologies of obtaining nanomaterials, types of nanostructures, properties of nanomaterials and their analysis methods; 2. to form an understanding of the growth process of different nanostructures, physical and chemical acquisition methods, types and properties of nanostructures, application of structural analysis, microscopy and spectroscopy methods in the field of nanotechnologies; 3. to promote the acquisition of the necessary knowledge, skills and competencies to perform practical work in the laboratories of the DU Innovative Microscopy Center (IMC) as well as to organize independent research work necessary for writing a master's thesis.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Describes the properties of nanostructured materials, their differences from macro-sized materials and their applications in different fields; 2. Are familiar with the types of nanostructures, physical and chemical technologies of their production, methods for determination the properties of nanostructures; 3. Understands the dependence of the properties of nanostructures on the production method and the synthesis parameters; 4. Are aware of the role of nanotechnologies in science and society, their development perspectives, benefits and risks;   Skills:   1. Independently finds, compiles and analyzes information and presents knowledge and understanding of the study subject; 2. Analyzes and plans experiments aimed at obtaining and characterizing a particular type of nanomaterial;   Competence:   1. Chooses appropriate methods for obtaining nanostructures, as well as analyzes methods for determination of structure and chemical composition depending on the purpose of application of nanostructured sample; 2. Justifies the choice of methods and plans the course of the experiment based on the goals and the desired result; 3. Makes responsible and fact-based decisions about developing their research skills. | |
| ***Course Plan*** | |
| 1. Nanostructures, nanomaterials, nanotechnologies. L6 S2  2. Nanostructures and nanomaterials obtaining technologies. L2  3. Chemical methods for obtaining of nanostructures. L4 S4 P4  4. Obtaining and classification of nanoclusters. L8 S2 P4  5. Physical methods for obtaining of nanostructures. L6 S4 P4  6. Technologies for analysing the properties of nanomaterials. L6 S4 P4  L – lecture, S – seminar, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| The students' individual work is planned after each lecture, improving the understanding of the topic / physical problem covered. It also provides preparation for seminars, practical assignment and mid-term examinations. Independent work includes: analysis of scientific articles and other literature sources according to the content of the study course, presentation creation, preparation for practical work at laboratory and summarization of work results.  Tasks for independent work:   1. Creation of presentation according to the seminar them; 2. Preparation for practical assignment at laboratory. Compilation and evaluation of practical assignment results; 3. Literature studies according to the topics of the seminars and research problems. | |
| ***Requirements for Awarding Credits*** | |
| Active participation in lectures, seminars and practical assignment at laboratory.  Systematic, independent analysis of the literature preparing for seminars and independent work tasks.  Intermediate tests:   1. Presentation: seminar topics 1-4 (topics can be chosen) - 10% 2. Presentation: seminar topics 5-8 (topics can be chosen) - 10% 3. Analysis of one scientific article on an innovative method or field of application of nanostructures (topics can be chosen) - 10% 4. Intermediate test 1: Preparation of report of practical work №1 or №2. – 20% 5. Intermediate test 2: Preparation of report of practical work №3 or № 4. – 20%   Final examination:  6. Exam (oral) - discussion on any of the course content questions - 30%  The final mark at the end of the study course comprises the assessment of independent work, mid-term examination and final examination results. Students take the exam only if they have completed their independent work and all mid-term examinations have been passed. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | | 1. 1. Intermediate test |  | + |  |  | + | + | + | + |  | | 1. 2. Intermediate test |  | + | + |  | + |  | + | + | + | | 1. Presentations | + | + | + |  | + |  |  |  | + | | 1. Analysis of one scientific article | + | + | + |  | + |  |  |  | + | | 1. Exam | + | + | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Kelsall, R.W., Hamley, I., Geoghegan, M. C. Nanoscale science and technology, England; Hoboken, NJ: John Wiley, c 2005. xv, 456 p. 2. Koch, C.C. (ed.) Nanostructured materials: processing, properties, and applications. 2nd ed. Norwich, NY William Andrew Pub.2007 3. Vollath, D. Nanomaterials. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KGaA, [2013]. x, 375 pages. 4. William, A. Nanostructured materials. Pub., 2007. xxiv, 760 p. | |
| ***Further Reading List*** | |
| 1. Birkholz, M. Film Analysis by X-Ray Scattering.Wiley VCH,2005 2. Ogurcovs, A. Promocijas darbs. Study of ZnO, CuO, CuInSe2 Compounds and Their Composites for Sensing Applications. Daugavpils, Latvia : Daugavpils Universitātes Akadēmiskais apgāds "Saule", 2017. 94 lpp 3. Oura, K., Lifshits, V.G. Surface science. An introduction. Springer, 2003 | |
| ***Periodicals and other sources*** | |
| 1. Beilstein journal of nanotechnology, <https://www.beilstein-journals.org/bjnano/home> 2. CrystEngComm, Royal society of chemistry, <https://www.rsc.org/journals-books-databases/about-journals/crystengcomm/> 3. Nanoscale Horizons, Royal society of chemistry, <https://www.rsc.org/journals-books-databases/about-journals/nanoscale-horizons/> 4. Nanotoday, Elsevier, <http://www.journals.elsevier.com/nano-today/> | |
| ***Course Content*** |  |
| Lecture topics (32h):   1. Introduction. Nanostructures, nanomaterials, nanotechnologies. Classification of nano-objects and nanostructures. Areas of application and development perspectives of nanostructured materials. 2. Structural peculiarities of submicrocrystalline materials. Nanoscale-induced changes of physical properties of materials. Mechanical, optical, electrical, magnetic properties of nanocrystals. 3. Nanostructures and nanomaterial obtaining technologies. Technology classification, advantages and disadvantages. Chemical and physical methods of obtaining. Hybrid methods. Methods with top-down and bottom-up approaches. Methods of mechanical production of nanomaterials. The concept of self-organization and self-assembly in nanotechnology. 4. Chemical methods for obtaining of nanostructures. Principles of classical inorganic synthesis. Formation and growth of nanoparticles. Homogeneous and heterogeneous nucleation. Coalescence, agglomeration and stabilization of nanoparticles. The concept of crystal growth rate. 5. Hydrothermal synthesis of nanostructures. Morphologies of nanostructures. Influence of hydrothermal synthesis parameters and seed layer on nanostructure formation process and morphology. 6. Laser-assisted synthesis of nanostructures. Laser-induced hydrothermal synthesis. Selective surface coating. Laser ablation in solution, air and vacuum. Laser pyrolysis. 7. Production and classification of nanoclusters. Cluster nanosystems. Matrix clusters and supramolecular nanostructures. Cluster models. Cluster reactions. Physical properties of clusters. 8. Synthesis of nanomaterials in micro- and nanoreactors. Colloidal nanoreactors. Mycelium. Inverse micelle method. Synthesis of nanostructures in microemulsions. Application of porous materials as micro- and nanoreactors. 9. Preparation of nanomaterials by sol-gel method. Preparation of Oxide Nanomaterials Using Metal-Polymer Gel. Synthesis of non-oxide nanoparticles and nanomaterials. 10. Electrochemical methods for the production of nanomaterials. 11. Physical technologies for obtaining nanostructures. Physical Vapour Deposition (PVD). Thermal deposition. Magnetron sputtering. Evaporation method with consolidation. 12. Thin films. Growth kinetics of thin films. Homoepitaxial and heteroepitaxial growth process. Physical properties of thin films. 13. Nanomanipulation and nanolithography. Electron beam-induced growth of nanostructures. Nanomanipulation by scanning probe microscopes. 14. Technologies for analyzing the properties of nanomaterials I. Methods of structural analysis. XRD analysis. EBSD. EDS. 15. Technologies for analyzing the properties of nanomaterials II. Spectroscopic methods. Optical spectrometry. Luminescence. Raman spectroscopy. X-ray absorption spectroscopy (XAS) methods. EXAFS, XANES 16. Technology for analyzing the properties of nanomaterials III. Microscopy. Electron microscopy. Scanning probe microscopy (atomic force microscopy, tunneling microscopy, near field optical microscopy).   Seminar topics (16h):   1. Nanostructure obtaining biomimetic approach. Nanostructures in nature. Methods of biological synthesis. 2. Soft Chemistry technologies for nanomaterial production. Photochemical and cryo-chemical synthesis of nanomaterials. Sonochemical and microwave synthesis of nanomaterials. 3. Chemical sputtering and spraying techniques. Chemical vapor deposition (CVD) technology. Plasma chemical deposition. Spray dry, freeze dry, plasma spray and hot spray. 4. Nanophase and nanocomposite materials. Types of nanocomposites. Molecular layering method. Other methods for obtaining nanophases and nanocomposites. 5. Ion beam technologies. Ion implantation. Molecular beam epitaxy (MBE). 6. Nanostructure modeling and mass production. Lithography. "Soft lithography". Nanoprint. Engineering modeling. Visual and digital modeling. 7. Nanofiber and porous nanoparticle production technologies. 8. Nanotechnologies and society. Prospects for the development of nanotechnology. Nanoscience.   Practical work topics (16h):   1. Hydrothermal synthesis of ZnO and CuO nanostructures. Equipment. Work safety. Design of experiment and selection of synthesis parameters. Substrate preparation. Preparation of working solution and choice of synthesis parameters depending on the resulting morphology. Synthesis process. Post-treatment and sample preparation for storage. 2. NiO electrochemical production method. Work safety. Deposition of nanostructures by electrochemical equipment Zanher. Choice of solution concentration and electrical parameters. 3. Sputtering technology. Sputtering with Quorum equipment. Magnetron and thermal metallic thin film sputtering. Carbon thin film sputtering. Magnetron sputtering with K.Lesker equipment. 4. Nanostructured sample analysis. Preparation of powder and epitaxial samples for measurement. Determination of nanostructures morphology and size by SEM. Selection of scanning mode and parameters. Determination of chemical composition by EDS method. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | **Non-linear optics and optical materials** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 32 |
| ***Number of Seminar and Practical Assignment Hours*** | 32 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 13.02.2021 |
| ***Course Developer*** | Dr. phys. E. Tamanis, Dr. phys. V. Paškevičs, Dr. phys. A. Salītis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** | |
| The aim of the course is to promote students’ systematic knowledge about optical materials and nonlinear optical effects - harmonic generation, parametric generation, multi-wave interaction, dynamic holography, optical orientation, optical frequency synthesizer, second optical harmonic generation effect in quantum electronics and communications.  Tasks of the course are:   1. to help build an understanding about nonlinear optical (NLO) materials (organic and inorganic), their types, structure, research methods; 2. to analyse the effects in NLO materials and application possibilities in modern technologies.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** | |
| Knowledge:   1. Understands the nature of non-linear optical effects, are able to explain the meaning of the phenomenon; 2. Describes types, properties and applications of modern advanced materials in optical technologies;   Skills:   1. Explains nonlinear effects using physical theories; 2. Evaluates scientific literature on the content of nonlinear optics and material physics;   Competence:   1. independently learns the latest research methods of modern optical materials and apply them in research work; 2. makes responsible and fact-based decisions about developing their research skills. | |
| ***Course Plan*** | |
| 1. Phenomenological thermodynamic (TD) description of nonlinear polarization of a substance. L4 2. Nonlinear Electrodynamics and Maxwell Equations - Equations of the principal NLO effects. Quantum mechanical description of the nonlinearity of a substance. L4 S2 3. Use of non-linearity in lasers and optical communication devices. L4 S4 4. Optical bistability. Self-interaction of light in matter. Self-focusing. L4 S4 5. Nonlinear optical materials. Square and cubic nonlinear optical materials (NLO), their classification, structure. Organic and inorganic NLO materials, liquid, gas and vapor NLO. L6 S6 6. Second and higher order nonlinear effects. Theory and modeling of nonlinear optical materials. Applications of optical materials in modern technologies. L6 S6 7. Nonlinear optical processes in organic molecules. L4 S6 8. Optical parameters of transparent substances and methods for their determination. S4   L – lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| The students' independent work is expected after each lecture, improving understanding of the physical problems considered and preparing for seminars, practical work, and inter-examinations. Independent work includes analysis of literature, scientific articles according to the content of the course, preparation for seminars and preparation of presentation.  Independent tasks:   1. Regularly read and analyze scientific information sources and report on planned seminar topics. 2. Prepare a presentation on a specific topic (optional, studying relevant scientific literature. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Intermediate Test 1: Preparation of a presentation and presentation at a seminar – 30% 2. Intermediate Test2: Preparing a presentation on the latest research on a problem and presenting it in a seminar – 30%   Final examination:   1. Exam – 40%   1. Presentation on one topic from the course,  2. Discussion and argumentation on some of the course content question.  The evaluation of the study course is formed by summing up the results of the seminars during the whole study course and the result of the final examination.  Students take the exam only if all intermediate examinations have been passed. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Intermediate Test 1 | + | + | + | + |  |  | | 1. Intermediate Test 2 |  | + | + | + | + |  | | 1. Examination | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Bloembergen, N. Nonlinear optics, W.A. Benjamin, Inc N.Y., Amsterdam, 1965, p.424. 2. Butcher, P.N., Cotter, D. The elements of Nonlinear Optics, Cambridge University Press, 1990, 344 lpp. 3. Karna, S.P., Yeates, A.T. (ed.) Nonlinear Optical Materials:Theory and Modeling, Amarican chemical society, Washington DC, 1996, 249p 4. Schaefer, B. Lerbuch der Experimentalphysik- Optik. Walter de Gryter, Berlin – New York, 1997 , 630 p. 5. Šens, Y.R. Nelineārās optikas principi. Maskava Nauka, Galvenā fiz.-mat. Literatūras red., 1989, 560 lpp. | |
| ***Further Reading List*** | |
| 1. Advances in Lasers and Applications, Proc. Of the 52 Scottish Universities Summer School in Physics, September, 1998, IoP Publishing, 346 lpp. | |
| ***Periodicals and other sources*** | |
| 1. Journal “Europhoponics” www.europhoponics.com 2. Journal “Materialstoday” www.materialstoday.com 3. Journal “Laser Focus World” www.laserfocusworld.com 4. Journal “Photonics spectra” [www.Photonics.com](http://www.Photonics.com) | |
| ***Course Content*** |  |
| 1. Introduction. Phenomenological TD description of nonlinear polarization of a substance. Simplified NLO polarization an-harmonic oscillator model. Nonlinear electrodynamics and Maxwell equations - equations of the main NLO effects. Interference features in NLO and phase synchronization. 2. Nonlinear electrodynamics and Maxwell equations - equations of the main NLO effects. Quantum mechanical description of the nonlinearity of a substance. Impact and energy conservation laws in NLO. Einstein-Podolsk-Rosen source and quantum teleportation experiments, NLO version of quantum computer. Quantum teleportation. Quantum computers. 3. Relationship of crystal lattice symmetry to nonlinear susceptible tensor components. Multi-wave interactions in optics, spatial aspects of NLO signal synthesis, dynamic holography and holographic recording media. Optical orientation of molecules. Photon band gap materials. 4. The use of nonlinearity in lasers and optical communication devices, the specifics of NLO in case of superimposed laser pulses. Principles of NLO spectroscopy. Second, third, fourth, etc. optical harmonics and their applications. Optical bistability. Femtosecond laser system. Methods of investigation of the effect of laser beam on material. 5. Self-interaction of light in matter. Self-focusing. Conditions for formation of optical solitons. 6. Non-linear optical materials. Electro-optical and magneto-optical effects. Non-linear magneto-optical effect. Calculation of second order dielectric susceptibility. Determination of higher order dielectric susceptibility. 7. Nonlinear properties of linked polymers. Nonlinear Optical Properties of Quasi Periodic Polymers. Nonlinear Effects of Linked Polymers in the Third Order. 8. Nonlinear optical processes in organic molecules. Determination of linear and nonlinear properties of molecules by Hartree - Fock method. Nonlinear optical materials for communication systems. Methods of obtaining nonlinear optical materials. Methods for the determination of optical fiber characteristics. Calculation of second order harmonics for different laser beams. Methods of determination of harmonics of higher order. Light propagation in organic molecules. Investigation of the interaction of light on polymers. Investigation of light self-focusing. Study of electro-optical and magneto-optical effect. Multiphoton photo effect study. 9. Optical parameters of transparent materials and methods of their determination: investigation of the relation between external electric field intensity and polarization of optical material; methods of determining electric field induction and polarization in various optical materials; determination of the refractive index at different wavelengths of light; determination of the angle of full internal reflection of various materials. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | **Practical holographic systems** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 8 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** | 8 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.phys. Andrejs Bulanovs |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to promote the development of students' knowledge and competencies about holographic recording technologies.  Tasks of the course are:   1. to master the theoretical foundations of optical holography; 2. to find out light-sensitive materials for holographic recording; 3. to get acquainted with the basic types of holograms (analog and digital) and their optical recording methods; 4. to get acquainted with optical lithography technology and its use for the production of protective holograms and diffraction elements; 5. to strengthen theoretical knowledge by performing practical and laboratory work with appropriate equipment.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains types of holographic recording, the basic principles of technology;   Skills:   1. Masters chemical methods of processing light sensitive holographic materials; 2. Performs a hologram calculation using a computer and prepare the data for lithographic recording;   Competence:   1. Designs simple laser optical systems, set them up and apply them to holographic recording; 2. Practically uses for recording holograms and diffraction optical elements of optical lithography equipment; 3. Analyzes and evaluates scientific literature on research according to the study course content. | |
| ***Course Plan*** | |
| 1. Theoretical basis of the holographic record. Recording principle and optical circuits for the production of basic hologram types. L2 S2 2. Digital and Analog Holography. Holographic stereograms. L2 S4 Ld4 3. Optical lithography techniques for the production of protective holograms and diffraction elements. L2 S4 Ld4 4. Theoretical basics of digital hologram calculation. L2 S6 Ld4   L – lecture, S – seminar, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is planned after each lecture and is related to the topic. Independent work is organized individually in preparation for seminars and laboratory works. Independent tasks:   1. To read and analyse scientific literature and make a review or presentation. 2. Preparation for laboratory work. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Laboratory work - 40%   Final examination:   1. Exam - 60%   Students are allowed to take the final examination if they have positive marks in all intermediate examinations (laboratory works). Active participation in lectures and seminars. Systematic and independent analysis of scientific literature, while preparing for seminars. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Intermediate test: laboratory work | + | + | + | + |  |  | | 1. Exam | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Hariharan, P. Basics of Holography, Cambrige University Press, ISBN 0521002001, 2002 2. Saxsby, G., Zaharova, S. Practical Holography (fourth edition) CRC Press. ISBN 9781482251579, 2015 | |
| ***Further Reading List*** | |
| 1. Holograms-Recording materials and applications, IntechOpen, ISBN 978-953-307-981-3, 2011 2. Holography. IntechOpen, ISBN 978-953-51-1117-7, 2013 | |
| ***Periodicals and other sources*** | |
| 1. Bulanovs, A., Gerbreders, S. Advanced concept for creation of security holograms, LJPT 50(6), 2013, DOI: 10.2478/lpts-2013-0041 2. Bulanovs, A., Bakanas, R. Use of Computer-Generated Holograms in Security Hologram Applications, LJPT 53(5) 2016, DOI: 10.1515/lpts-2016-0036 | |
| ***Course Content*** |  |
| 1. Theoretical basis of the holographic record. Recording principle and optical circuits for the production of basic hologram types. L2 S2    1. Introduction. Principles of holography. Basic types of holograms.    2. Analysis of information obtained from literature sources about lasers and optomechanical elements used in holography. Laser transmission holograms. 2. Digital and Analog Holography. Holographic stereograms. L2 S4 Ld4    1. Analog and digital holography.    2. Analysis of information obtained in literature sources on obtaining white light reflection holograms and on Denisyuk method.    3. Analysis of information on rainbow holograms obtained in literature sources. Holographic stereogram technology.    4. Basics of digital holography. Optical diffraction elements and their applications. 3. Optical lithography techniques for the production of protective holograms and diffraction elements. L2 S4 Ld4    1. Holographic stereograms. Security holograms.    2. Analysis of information on optical lithography obtained in literature sources. Security hologram recording technology.    3. Laser radiation optical filtration methods and their application in holography.    4. Design and basics of digital hologram recording equipment. 4. Theoretical basics of digital hologram calculation. L2 S6 Ld4    1. Computer-generated holograms and diffractive optical elements.    2. Materials for holographic recording. Coating plates with photoresist 'Spin coating' methods for holographic recording.    3. Optical components for holography. Creating optical circuits for hologram recording.    4. Basics of holographic design. Hologram recording on a photoresist and relief-phase hologram creation.    5. Creation of digital hologram structures and recording on photoresist.    6. Basics of galvanization and its application in relief-phase hologram copying. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | **Basics of industrial robotics** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 32 |
| ***Number of Seminar and Practical Assignment Hours*** | 32 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 19.02.2021 |
| ***Course Developer*** | Dr. Paed. Pāvels Drozdovs, Dr. phys. Pāvels Narica, Mg.sc.ing. Sergejs Ločs, Mg.sc.ing. Guntis Spriņģis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to promote the development of students' knowledge and competencies about the design, applications, programming methods of industrial robots and cyber-physical systems.  Tasks of he course are:   1. to acquire knowledge and skills to create a simulation of processing processes for the robot Robotmaster and RobotStudio software; 2. to analyze the principles of operation of cyber-physical systems and to acquire the skills to organize system protection measures during operation; 3. to practice activating and calibrating the KUKA robot, creating and changing programmable movements using the KUKA robot control buttons; 4. to compile a part processing program and checking the ability of this program to operate using OrangeEdit; 5. to acquire the necessary competencies to work in Mastercam application software.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Identifies types and applications of different robots, robotic systems and cyber-physical systems; 2. Understands the design and function of robots, their actuators and accessories; 3. Understands RobotStudio, Mastercam and Robotmaster application software and basics of programming; 4. Explains maintenance and safety requirements when working with robots and cyber-physical systems;   Skills:   1. Obtains information and analyzes technical characteristics, control and information systems of different robots; 2. Uses KRL (Kuka Robot Language) programming language for programming the operations of KUKA robot; 3. Evaluates the usage of cyber-physical systems in automation and manufacturing companies; 4. Explains integration of autonomous industrial robots into computerized systems and interaction between robots;   Competence:   1. Programs KUKA robot movements using KRL; 2. Creates processing programs in KRL; 3. Programs inputs/outputs using KRL; 4. Creates simulation process of machining; 5. Justifies the usefulness of cyber-physical systems, the necessity of their implementation in automation and production. | |
| ***Course Plan*** | |
| 1. Introduction to robotics. Basic concepts of robots and robotic systems. Classification of robots. L2 S2. 2. Structure of industrial robots and robotic systems. Basic principles of robot’s design and construction. L2 S2. 3. Main technical characteristics and kinematic diagrams of industrial robots. L2 4. Equipment of robots, its application for various tasks. Applications of industrial robots. L2 S2. 5. Types of robot drive. Robot’s control and information systems. L2, S2. 6. Various software specifics for the creation of processing programs for the machining of materials by robot. L2 S4 7. KUKA robot. L2 P6 8. On-line programming. L2 P6 9. Off-line programming. L2 10. Introduction to Robotmaster application software. L2 11. Robots’ maintenance and safety requirements. L2 12. Cyber-physical systems (CFS). L2 S4 13. CFS in automation and manufacturing. L4 P2 14. Integration of autonomous industrial robots into computerized systems. L2 P2 15. Security and privacy of cyber-physical systems. L2   L – lecture, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is needed after each lecture in order to better understand the topic covered in the lesson and to prepare for seminars, practical assignments and intermediate examinations.  Independent work includes: analysis of literature sources, analysis of scientific articles according to the study course content, preparation of a presentation.  Independent tasks:   1. To select and analyse scientific sources and to prepare an overview of the robot used in an industrial or manufacturing sphere, its applications, technical characteristics and advantages. 2. Obtain and compile technical information of robots’ classification. 3. Analyse applications of ABB and KUKA robots in industrial and manufacturing spheres. 4. Analyse information of robotic technical surveillance systems. 5. Obtain and analyse up-to-date information on the usage of cyber-physical systems (CFS) for production process planning, product development and control. 6. Get to know the requirements of robot maintenance and safety techniques. 7. Collect information on how to use the Mastercam application software by creating a detail’s machining program for KUKA robot. | |
| ***Requirements for Awarding Credits*** | |
| Active participation in lectures and seminars.  A systematic, independent analysis of the indicated literature. The presentation in the seminars or submission of this literature analysis afterwards.  Intermediate examinations. Individual papers are submitted or presented in seminars.  Intermediate tests:   1. Intermediate Test 1. Creating a detail’s flat surface machining trajectory in Mastercam application software - 30%. 2. Intermediate Test 2. Optionally find, analyse, summarize and present information on two topics of the course content in the seminars, to justify the opinion and answer the questions - 30%.   Final examination:   1. Type of final examination - exam on two questions of the course content - 40%.   The final evaluation of the study course acquisition is formed by summing up the results of the intermediate examinations and the results of the final examination. Students are allowed to take the final exam if they pass all intermediate examinations. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Pārbaudījumu veidi | Studiju rezultāti | | | | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | | 1. Intermediate exam - “Creating a flat surface machining trajectory for a detail.” | + |  | + |  |  | + |  |  | + | + | + | + |  | | 1. Intermediate exam - make a presentation of one of the themes of the course. | + | + |  | + | + | + | + | + |  |  |  |  |  | | 1. Exam | + | + | + | + | + | + | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. ACATECH – Deutsche Akademie der Technikwissenschaften: Autonome Systeme – Chancen und Risiken für Wirtschaft, Wissenschaft und Gesellschaft. Zwischenbericht, Berlin (2016). 2. Druml, N., Genser, A., Krieg A., Menghin M., Hoeller Andr., Solutions for Cyber-Physical Systems Ubiquity, ISBN13:9781522528456, 2017. 3. Lambert, M. Surhone, Mariam T. Tennoe, Susan F. Henssonow, Cyber-Physical System, ISBN: 978-6-1345-2434-6, 2011. | |
| ***Further Reading List*** | |
| 1. Broy M., Cyber-Physical Systems, Springer-Verlag Berlin Heidelberg 2010. 2. Gasparetto, L. Scalera. A Brief History of Industrial Robotics in the 20th Century. Advances in Historical Studies, 2019, 8, 24-35. DOI: 10.4236/ahs.2019.81002 Feb. 15, 2019. 3. N. Muro, N., Lewis. F. L., Abdallah, C. T. Robot Manipulator Control. Theory and Practice- Second Edition. Marcel Dekker inc. 2004; 5. Adaptive Control of Robot Manipulators, An-Chyan Huang and Ming-Chih Chien. ISBN: 978981-4307-41-3, 226. lpp, 2010. 4. Richard L. Shell, Ernest L. Hall. Handbook of Industrial Automation. 2000 Marced Dekker Inc. http://www.fuzzytech.com/. 5. Robot History. https://ifr.org/robot-history. 6. Robotics and Automation Part 1:6 common types of industrial robots and their functions within the manufacturing field. Skatīt: http://marii.my/robotics-and-automation-part-1-5-common-types-of-industrial-robots-and-their-functions-within-the-manufacturing-field/ | |
| ***Periodicals and other sources*** | |
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| ***Course Content*** |  |
| 1. Introduction to robotics. An insight into the history of industrial robotics development. The usage of robots for automatization of work processes. Basic concepts of robots and robotic systems - robot, industrial robot, manipulator, object of manipulation, auto-operator, etc. Robot classification by: the type of the operations that could be performed; specializations; movements taking into account the coordinate system; type of drive; program processing capabilities; the speed and programming options for discrete moves.   Seminar. Basic types of robots and technical characteristics.   1. Structure of industrial robots and robotic systems. Control system. Information system. Mechanical system. Basic principles of robot design and construction. Modular approach to industrial robot construction.   Seminar. Adaptive robots.   1. Main technical characteristics (number of possible motions, speed, lifetime, positioning accuracy, etc.) and kinematic diagrams of industrial robots. 2. Equipment of robots, its application for various tasks. Classification of grippers. Robots’ equipment with cutting tools and welding accessories. Applications of industrial robots.   Seminar. ABB Robot, application, features.   1. Types of robot drives (pneumatic drive, hydraulic drive, electric drive, combination drive). Robots control and information systems. Transducers of internal information.   Seminar. Technical monitoring systems.   1. Various software specifics for the creation of processing programs for the machining of materials by robot. Criteria for selecting the required software application.   Seminar. Robot programming using RobotStudio application software.   1. KUKA robot, its main components. KR C4 controller.   Practical assignment. KUKA robot’s structure and functions. Overview of the mechanical parts of KUKA robot. Operation of KR C4 controller. KUKA Smartpad. Robot’s control. Robot’s activation, calibration.  Practical assignment. Creating and modifying programmable movements using KUKA robot’s control commands.   1. On-line programming. KUKA system software. KRL programming language.   Practical assignment. Using management programs to control functions.  Practical assignment. Variables and data.  Practical assignment. Programming of conditional transitions, shifter, cycles, waiting functions, time and signal waiting functions.  Practical assignment. Test of the ability of function of the program using OrangeEdit.   1. Off-line programming. Work on Mastercam application software. Creation of model and machining trajectory. L2 2. Introduction to Robotmaster application software, settings and simulation possibilities. 3. Robots’ maintenance and safety requirements. 4. Cyber-physical systems (CFS) - the basis of the manufacturing process according to the Industrie 4.0 concept and the technical prerequisites for the occurrence of cyber-physical systems.   Seminar. CFS for production process planning, product development and control.   1. CFS in automation and manufacturing, connection to mechatronic systems, sensors, actuators, intelligent systems and their networking, communication systems.   Practical assignment. Sensors and transducers for obtaining information on the current state of the robotic system.   1. Integration of autonomous industrial robots into computerized systems, interaction between robots and automated customization of operation.   Practical assignment. Actuators and drives of a robotic system.   1. Security and privacy of cyber-physical systems, design and protection measures during operation’s time. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | **Spectroscopic methods** |
|  | Physics and astronomy |
| ***Credits*** | *2* |
| ***Total Number of Contact Hours*** | *32* |
| ***Number of Lecture Hours*** | 16 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Mg.phys. Inga Pudža |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to promote the development of students' knowledge and competencies on spectroscopy techniques and their application in the study of the structure and properties of atoms, molecules and solids in materials science and recent research in this field.  Tasks of the course are:   1. to help build an understanding about the interaction of electromagnetic radiation of different wavelengths with a substance; 2. to consider the most important experimental spectroscopic methods for the study of optical, structural, electronic and dynamic properties of materials; 3. to get acquainted with their physical nature and principles of realization.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands the types of spectroscopic methods and their application in the study of material properties; 2. Describes the physical principles and theoretical models of spectroscopic techniques; 3. Understands the technical realization of spectroscopy;  Skills: 4. Obtains and analyses information on the feasibility of applying different spectroscopic techniques in material research; 5. Analyzes the spectroscopic measurement data;   Competence:   1. Chooses a spectroscopic method according to the purpose and to evaluate its advantages and limitations; 2. Analyzes and interprets data obtained in spectral analysis. | |
| ***Course Plan*** | |
| 1. Spectral Apparatus and Spectral Measurements. L2 S2 2. Theory and types of luminescence.L2 S2 3. Infrared Fourier Spectroscopy. L2, S2 4. Raman Spectroscopy. L2 S2 5. X-ray Absorption Spectroscopy. L2 S2 6. Photoelectron Spectroscopy (XPS, UPS). L2 S2 7. Magnetic resonance spectroscopy (EPR, NMR). L2 S2 8. Other spectroscopic methods (X-ray fluorescence, Mass Spectrometry, Chromatography, Moessbauer spectroscopy, etc.). L2 S2   L – lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is planned after each lecture and is related to the spectroscopic method introduced in the lecture. While studying the lecture materials, students perform the test. Independent work is organized individually in preparation for seminars and mid-term examinations.  Independent tasks:        1. To read and analyse scientific literature and make a review or presentation on the applications of spectroscopic methods in the chosen field of research.        2. Answering test questions. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:  1. Intermediate test: Test questions - 40%  2. Intermediate test: Preparation of presentation, oral talk - 20%  Final examination:   1. Exam - 40%   The exam includes:   1. description of one spectroscopic method; 2. a written test on the content of the course.   Students can take the exam only if they have completed their independent work.  The final evaluation of the gained knowledge in the course is formed by summing up the results of intermediate examinations during the whole course of study. Students are allowed to take the final examination if they have positive marks in all intermediate examinations. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1.Intermediate examination. Test questions. | + | + | + | + |  |  |  | | 2. Intermediate examination. Presentation. | + | + | + | + | + | + |  | | 3. Exam | + | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Demtröder, W. Laser spectroscopy: basic concepts and instrumentation, Springer, 2003. 2. Demtröder, W. Atoms, Molecules and Photons. Springer-Verlag, Berlin, Heidelberg, 2006. 3. Sparkman, O. David. Gas chromatography and mass spectrometry: a practical guide / O. David Sparkman, Zelda E. Penton, Fulton G. Kitson. - 2nd edition. - Boston: Elsevier, 2011. - xix, 611 lpp.: il.; 23 cm. - ISBN 9780123736284 4. Svanberg, S. Atomic and Molecular Spectroscopy, Springer, 2006. | |
| ***Further Reading List*** | |
| 1. Eiduss, J., Zirnītis, U. Atomfizika, Rīga „Zvaigzne” 1978, 328lpp. 2. Halliday, D., Resnick, R., Walker, J. Fundamentals of Physics, 6th edition, New York, etc., John Wiley & Sons, Inc.”, 2001, 1139 pages. 3. Smith, F.G., King, T.A. Wilkins D. Optics and Photonics: An Introduction. John Wiley and Sons. 2007, 499 p. | |
| ***Periodicals and other sources*** | |
| 1. Physical Mesurement Laboratory: Atomic Spectroscopy - A Compendium of Basic Ideas, Notation, Data, and Formulas, <http://www.nist.gov/pml/pubs/atspec/index.cfm> 2. Physical Mesurement Laboratory: X-Ray Form Factor, Attenuation, and Scattering Tables, <https://www.nist.gov/pml/x-ray-form-factor-attenuation-and-scattering-tables> 3. Wiley Analytical Science: Latest Spectroscopy Articles, <http://www.spectroscopynow.com> | |
| ***Course Content*** |  |

1. Introduction. Spectral apparatus and spectral measurements.

Electromagnetic spectrum. Types of spectra. Radiation sources (continuous spectrum lamps, discharge lamps, lasers). Types of spectral apparatus. Properties of spectral lines, their broadening, resolution, Relay criteria. Detectors (photo-plates, electron multipliers, photodiode, CCD camera, scintillators, ionization cameras);

Seminar: Spectral apparatus and spectral measurements.

2. Luminescence theory.

Photoluminescence. Photostimulated luminescence. Thermostimulated luminescence. Up-Transformed Luminescence, its applications.

Seminar: Theory and types of luminescence.

3. Infrared Fourier spectroscopy.

IR absorption mechanisms. Fourier spectroscopy, its applications.

Seminar: Infrared Fourier spectroscopy.

4. Raman spectroscopy.

The basics of combinative light scattering.

Seminar: Raman spectroscopy.

5. X-ray absorption spectroscopy.

X-ray lamp. Synchrotron. X-ray absorption spectrum (EXAFS, XANES).

Seminar: X-ray absorption spectroscopy.

6. Photoelectron spectroscopy.

XPS (X-ray photoelectron spectroscopy). UPS (ultraviolet photoelectron spectroscopy).

Seminar: Photoelectron spectroscopy.

7. Magnetic resonance spectroscopy. EPR (electron paramagnetic resonance).

KPR (nuclear paramagnetic resonance).

ODMR (Optically Detected Magnetic Resonance).

Seminar: Magnetic resonance spectroscopy.

8. Other spectroscopic methods. (X-ray Fluorescence, Mass spectrometry, Chromatography, Mesbauer spectroscopy, etc.).

Seminar: Students' presentations on actual, course-related topics.

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | **Modeling of technological processes** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** |  |
| ***Number of Seminar and Practical Assignment Hours*** | 32 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Mg. Sc. Comp. A. Vagalis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course to promote the development of master students' knowledge and competences in the management and modeling of modern technological processes using CNC software.  Tasks of  the course are:   1. to acquire  aspects of the organization of  production process; 2. to get basic skills for working with automated engineering and modelling software for technological processes.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Describes software that can be used to design and model production technological processes;   Skills:   1. Prepares CAM software; 2. Designs, models and tests production technological processes;   Competence:   1. Chooses the most appropriate tools and solutions for modelling technological processes and apply them in practice; 2. Makes responsible and fact-based decisions about improving one’s skills. | |
| ***Course Plan*** | |
| 1. Production process modelling tools and software. S2 2. Milling Programs and Programming of Processes. P4 3. Using 3D CAM systems for development and modelling of technological processes. P8 4. Creating a Cleanup Process. P6 5. Modelling, testing, optimization of technological process of component creation. P6 6. Tuning, adjustment and testing of the manufacturing program created for a specific machine tool. P6   S – seminar, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is planned after each class, improving understanding of the CAM software part and technological process.  Independent tasks:  1. Independently select an item with technical drawings and create a program for manufacturing the item using milling (drilling, tapping, linear and circular motions) (Pd8);  2. Independently select an item with technical drawings and create a program for manufacturing the item using milling (built-in milling cycles, absolute, relative and polar coordinates) (Pd8);  3. Creating a 3D model of an item using 3D CAD Software (Pd6);  4. Importing the created part into the CAM system. Development, testing and modelling of manufacturing process (Pd16);  5. Creation of 3D model of the part, development, testing and modelling of the manufacturing technological process by turning. (Pd10) | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Practical tasks during the course - 40% 2. Independent creation of milling tasks, program creation using G and M-codes and presentation - 20%   Final examination:   1. Exam - the creation and modelling of the technological process of manufacturing the item - 40%   The final assessment of the study course consists of the assessment of independent work and examination. Students take the exam only if they have completed all independent tasks. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | 1. | 2. | 3. | 4. | 5. | | 1. Practical tasks | + | + | + |  | + | | 1. Independent task and presentation |  |  |  |  |  | | 1. Exam | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Manton, M., Weidinger, D. Mastercam X9 Training Guide Mill 3D. 2015. CamInstructor Inc., 350p. ISBN-13: 978-1927359730 2. SINUMERIK 840D sl/840Di sl/840D/840Di/810D Fundamentals. Programming Manual. Copyright © Siemens AG 2006. 560p. 3. Smid, P. CNC Programming Handbook, 3rd edition. 2007. Industrial Press, Inc.; 600p. ISBN-13: 978-0831133474 4. Smid, P.CNC Programming Techniques. 1st edition. 2005. Industrial Press, Inc.; 360p. ISBN-13: 978-0831131852 | |
| ***Further Reading List*** | |
|  | |
| ***Periodicals and other sources*** | |
|  | |
| ***Course Content*** |  |
| 1. Production process modelling tools and software. S2 2. Milling Programs and Programming of Processes. P4   2.1. Creating a milling machining process using G and M codes. Structure of the milling program.  2.2. Programming of simple operations (linear motion and drilling).  2.3. Use of circular motions in milling process.  2.4. Polar and relative coordinates in the milling process.   1. Using 3D CAM systems for development and modelling of technological processes. P8   3.1. Creation and preparation of a virtual 3D model for development and modelling of a technological process.  3.2. Select the machine group and load the 3D model into the part.  3.3. Define workpiece parameters and create virtual tools.  3.4. Creating trajectories for simple processing operations.  3.5. Creation of drilling, threading and milling trajectories.   1. Creating a Cleanup Process. P6 2. Modelling, testing, optimization of technological process of component creation. P6   5.1. Development and export of the part processing technological process processing program.   1. Tuning, adjustment and testing of the manufacturing program created for a specific machine tool. P6 | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | **Vacuum Tecnology** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 16 |
| ***Number of Seminar and Practical Assignment Hours*** | 0 |
| ***Number of Laboratory Work Hours*** | 16 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 17.03.2021 |
| ***Course Developer*** | Dr. phys. Edmunds Tamanis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to master the principles of the construction and operation of vacuum equipment, to work with vacuum equipment.  Tasks of the study course are:   1. to help build an understanding the principles of vacuum achieving; 2. to analyze the most popular methods and equipment design principles, vacuum measurement principles and equipment; 3. to obtain practical skills in working with vacuum equipment.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands the principles and techniques of vacuum achieving; 2. Understands the design of vacuum equipment and vacuum gauges;   Skills:   1. Works independently with DU vacuum equipment; 2. Performs elementary maintenance of the vacuum equipment;   Competence:   1. Independently evaluates and selects suitable vacuum achieving methods for the job; 2. Independently studies the latest vacuum techniques and applying them in research or industrial applications. | |
| ***Course Plan*** | |
| 1. History of vacuum achieving; Theoretical principles of vacuum achieving, calculation of vacuum systems. L4 2. Vacuum pump types: fore-vacuum mechanical pumps, diffusion pumps; Fore-vacuum; Medium Vacuum System. L2 Ld6 3. Types of vacuum pumps: turbomolecular pumps, cryogenic pumps, ionization pumps, magnetrons; High vacuum system. L2 Ld2 4. Achieving an oil free vacuum; SEM and XRD vacuum system. L2 Ld2 5. Theory of vacuum measurement, vacuum gauges; Using a vacuum system - producing a coating; Vacuum gauges, principles of operation, use. L2 Ld4 6. Ultra-high vacuum - achieving and measurement principles. Vacuum system maintenance principles, leak detection; Vacuum system and pump maintenance. L4 Ld2   L – lecture, Ld – laboratory works | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is planned after each lecture and is related to the topic.  Student work is organized individually and in groups, independently preparing for laboratory work.  Independent work tasks:   1. Independent acquaintance with the theory corresponding to a specific laboratory work; 2. Studying relevant scientific literature. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate test:   1. Regular attendance and active work in classes - 10% 2. Laboratory work Nr.1 - 10% 3. Laboratory work Nr.2 - 10% 4. Laboratory work Nr.3 - 10% 5. Laboratory work Nr.4 - 10% 6. Laboratory work Nr.5 - 10% 7. Laboratory work Nr.6 - 10% 8. Laboratory work Nr.7 - 10%   Final test:   1. Exam (oral) - 20%   The evaluation of the study course is formed by summing up the results of laboratory work during the whole course of studies. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assesment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Work in classes | + | + | + | + | + | + | + | | 1. 1.- 4. Laboratory work | + | + |  |  |  | + | | 1. 5. - 6. Laboratory work |  | + | + |  | + | + | | 1. 7.Laboratory work | + | + | + | + | + | + | | 1. Exam | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Roth, A. Vacuum Technology. North-Holland Publishing Company. 1976 2. Wutz, M., Adam, H., W. Walcher, W. Theorie und Praxis der Vakuumtechnik. Friedr. Vieweg& Sohn Verlagsgesellschaft mbH, Braunschweig, 198 | |
| ***Further Reading List*** | |
| 1. Weston, G.F. Ultrahigh vacuum practice. Butterworth & Co. 1985 | |
| ***Periodicals and other sources*** | |
| 1. Aydil, E. (ed.) Journal of Vacuum Science & Technology. 2. Hultman, L.G. (ed.) Vacuum; | |
| ***Course Content*** |  |
|  | |

1. Vacuum history: Heron syringe, Ketezby water pump; The role of Leiden Reneri, Gasparo Berti, Vincenzo Viviani, Evangelisto Toricelli and Otto von Gerike in the development of the concept of vacuum. Theoretical principles of vacuum achieving: the concept of vacuum, the definition of vacuum stages, the hypotheses of the molecular-kinetic theory used. Theory of pumping process, calculation of vacuum systems.;
2. Types of vacuum pumps: breakdown of vacuum pumps by type of gas transfer. Volumetric pumps: mechanical fore-vacuum pumps, diffusion pumps.;
   1. Laboratory work: Fore-vacuum.
   2. Laboratory work: Medium vacuum system.
3. Types of vacuum pumps: molecular pumps, turbomolecular pumps. Sorbtion pumps: cryogenic pumps, ionization pumps, magnetrons.
   1. Laboratory work: High vacuum system.
4. Obtaining an oil-free vacuum: negative consequences of oil pollution formation on processes, pollution reduction techniques, choice of pumps
   1. Laboratory work: SEM and XRD vacuum systems.
5. Theory of vacuum measurement: Vacuum gauges, their division according to the principle of operation. Pressure manometers, viscosity manometers, pulse transfer manometers, thermal conductivity manometers, ionization manometers, their operating principles.
   1. Laboratory work: Using a vacuum system - obtaining a coating.
   2. Laboratory work: Vacuum gauges, principles of operation, using.
6. Ultra-high vacuum: the concept of ultra-high vacuum, its acquisition and measurement methods. Maintenance principles of vacuum systems: sealing, its selection, prevention of air pockets, cleanliness of the chamber, need for heating. Computer control of vacuum systems.
   1. Laboratory work: Vacuum system and pump maintenance.

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | **Industrial use of laser technologies** |
|  | Physics and astronomy |
| ***Credits*** | *4* |
| ***Total Number of Contact Hours*** | *64* |
| ***Number of Lecture Hours*** | 32 |
| ***Number of Seminar and Practical Assignment Hours*** | 16 |
| ***Number of Laboratory Work Hours*** | 16 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr. Phys. Edmunds Tamanis  Dr Phys., Pāvels Narica |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to facilitate students' theoretical and practical training in the safe operation of laser equipment in industry and research institutions.  Tasks of the study course are:   1. to help build an understanding about  the specifics of industrial use of laser technologies, constructional properties of laser systems; 2. to analyze variety of methods of laser processing of materials, to use of laser beam for diagnostic and metrological purposes; 3. to promote students’ practical skills and competencies in working with equipment and systems that use a laser beam as a working tool.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands regulatory documents in the field of laser application safety; 2. Is aware of risk factors when working with laser systems and principles of selection of protective equipment; 3. Understands laser beam properties, laser radiation quality diagnostic methods; 4. Understands the design of laser systems;   Skills:   1. Chooses protective equipment when working with laser equipment; 2. Performs laser radiation diagnostics and practically uses laser systems for processing various materials; 3. analyzes the results of laser processing;   Competence:   1. Evaluates risk factors when working with laser systems; 2. Selects appropriate parameter values for laser processing; 3. Plans and analyzes the laser processing process; 4. Makes responsible and fact-based decisions about developing one's professional competence. | |
| ***Course Plan*** | |
| 1. Occupational safety when working with laser systems. Justification and calculation of security measures. Reduction of risk factors in working area of laser system, conditions and principles of choice of aspiration systems. L3 S4 2. Laser beam properties, parameters. Laser radiation diagnostics. L3 S2 Ld2 3. Interaction of laser beam with metals and non-metals – reflection. Material heating characteristics, temperature front depth, heating and cooling rates, temperature gradient, critical values of power densities. Heat processes – heating, smelting, ablation. L8 S2 Ld4 4. Optimal conditions for different laser processing processes (welding, cutting, engraving, microtechnology and others). Impact of laser system parameter values processing results. L8 S2 Ld4 5. Functions and physical basis of basic components of laser systems: optical light switches (electro-optical and acoustic), non-linear optical elements. L4 S2 6. Functional nodes for laser processing (laser scanners, coordinate systems). L4 S2 Ld2 7. Use of lasers in metrology. Diagnostic and measuring equipment based on the use of a laser beam. L2 S2 Ld4   L – lecture, S – seminar, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| The student's independent work is planned after each lecture. Independent work is organized individually and in groups, independently preparing for seminars and laboratory works, mid-term examinations.  Tasks of independent work:   1. To study lab protection requirements when working with lasers, studying normative documents and scientific literature; 2. To compile methods of laser beam parameter measurement while studying literature; 3. Studying Literature, Creating a Review or Presentation on the Interaction of Laser Beam with Metals and Nonmetals; 4. To study the laser processing process by studying the literature; 5. Prepare an overview of the operation of the components of a laser system. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Systematic, independent analysis of the literature in preparation for seminars and practical work - 10% 2. Development and defense of laboratory works - 25% 3. Development and defense of a research project - 30%   Final examination:   1. Exam (oral) - discussion on some of the course content questions - 35%   Final assessment of the study course consists of independent work, laboratory work, research project development and defense and examination assessment. Students take the exam only if all the laboratory work and research project have been developed. | |
| ***Criteria for Evaluation Learning Outcomes*** | |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of study results***   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Types of assessment | Learning outcomes | | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | | 1. Preparation for seminars and practical works | x | x | x | x | x | x | x | x | x | x | x | | 1. Intermediate test. Defense of laboratory works |  |  |  | x | x | x | x |  |  |  | x | | 1. Intermediate test   Research project defense |  |  |  |  |  | x | x | x | x | x | x | | 1. Exam | x | x | x | x |  |  |  | x |  |  | x | | |
| ***Compulsory Reading List*** | |
| 1. Bauer H., Lasertechnik, Grundlagen und Anwendungen; Würzburg, Kamprath-Reihe Vogel, 1991 2. Bliedtner, Je., Muller, H., Barz, A., Lasermaterialbearbeitung, Leipzig, Fachbuchverlag, 2013 3. Eichhorn, M. Laser physics: from principles to practical work in the lab: Eichhorn Marc, 1st edition. - New York: Springer - 171 p. ISBN 9783319051277, 2014 4. Jakubczak ,Krz.; Laser Systems for Applications; 10.5772/903; ISBN :978-953-307-429-0; eBook (PDF) ISBN: 978-953-51-4914; <https://www.intechopen.com/books/laser-systems-for-applications>: 2011. | |
| ***Further Reading List*** | |
| 1. Chryssolouris G.; Laser Machining: Theory and Practice; Springer Science & Business Media; ISBN 9781475740844; 2013 2. Csele M., Fundamental of Light Sources and Lasers; <https://www.wiley.com/en-us/Fundamentals+of+Light+Sources+and+Lasers-p-9780471476603> ; 2004 3. Naumann H., Schröder G., Bauelemente der Optik: Taschenbuch der technischen Optik, Fachbuchverlag Leipzig, ISBN: 3446170367; 1992 4. Pedrotti F., Pedrotti L., Bausch W, Schmidt H., Optik für Ingenieure: Grundlagen; Springer Verlag, 4. bearb., 2008 5. William T. Silfvast, Laser Fundamentals, Second Edition; ISBN-10: 0521541050, ISBN-13: 978-0521541053; 2008 | |
| ***Periodicals and other sources*** | |
| 1. Ministry of Education and Science website: www.izm.gov.lv 2. Laseroptik Online Portal, www.laseroptik.de/loop 3. The world of 3D laser processing at TRUMPF, www.trumpf.com/s/do-anything 4. The publication for integrators and users of laser systems from the team behind Electro Optics magazine, www.lasersystemseurope.com 5. Photonik, www.photonik.de | |
| ***Course Content*** |  |
| 1. Occupational safety when working with laser systems. L3 S4   Justification and calculation of security measures.  Reduction of risk factors in working area of laser system, conditions and principles of choice of aspiration systems.  Design of security system for different types of laser. Choice of protective goggles from laser radiation.  Impact of laser beam parameter values on processing results.   1. Laser beam properties, parameters. L3 S2 Ld2   Laser radiation diagnostics.  Need for laser system parameters for different laser processing processes.  Investigation of physical properties of laser beam.   1. Interaction of laser beam with metals and non-metals – reflection. L8 S2 Ld4   Material heating characteristics, temperature front depth, heating and cooling rates, temperature gradient, critical values of power densities.  Heat processes – heating, smelting, ablation.  Analysis and critical evaluation of information obtained from literature on laser processing processes.  Operation of security system sensors.  Laser beam power measurement.   1. Optimal conditions for different laser processing processes (welding, cutting, engraving, microtechnology and others). L8 S2 Ld4   Impact of laser system parameter values processing results.  Diagnostic capabilities of the main components of laser systems.  Laser system programming, laser beam trajectory and parameters.  Laser cutting, analysis of the influence of system parameter values.   1. Functions and physical basis of basic components of laser systems: optical light switches (electro-optical and acoustic), non-linear optical elements. L4 S2   Maintenance of laser system components.   1. Functional nodes for laser processing (laser scanners, coordinate systems). L4 S2 Ld2   Analysis of information about distance and angle measuring equipment.  Laser welding, analysis of influence of system parameter values.   1. Use of lasers in metrology. L2 S2 Ld4   Diagnostic and measuring equipment based on the use of a laser beam.  Laser scanning systems and their applications in reverse engineering.  Laser melting, analysis of influence of system parameter values.  Analysis of laser instrument distance measurement error. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Current topics in physics and astronomy II*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 18 |
| ***Number of Seminar and Practical Assignment Hours*** | 14 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 18.03.2021 |
| ***Course Developer*** | Dr.phys. Tija Sīle  Dr.phys. Guntars Kitenbergs |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the study course is to stimulate student knowledge and understanding in newest scientific discoveries, while simultaneously developing their soft skills, particularly science communication skills.  This course is an elective course that follows Fizi5132 Current topics in physics and astronomy I, for students that want to continue soft skill development and seminar attendance.  Tasks of the study course are:  1. to master different scientific information research and communication types;  2. to get to know principles of modern physics education methods;  3. to learn about current research topics in the students field of interest in physics, astronomy and connected disciplines.  Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:  1. knows several actual topics in various disciplines of physics and astronomy, their use in interdisciplinary fields (MN8) and qualitatively understand the development of these topics;  2. manages terminology in English and Latvian about several current topics in physics and astronomy;  Skills:  3. finds, reads, analyzes and uses scientific literature;  4. presents and discusses scientific results in English and Latvian;  5. manages time, individual work and constructive collaboration with colleagues with various academic experience in order to reach study results;  6. prepares a part of a lecture or presentation, using ideas from modern physics education research;  Competence:  7. explains concepts and ideas of scientific literature in a structured way;  8. chooses and uses proper type of presentation to convey scientific information, depending on audience, contents and other factors. | |
| ***Course Plan*** | |
| 1. Introduction. Course structure, aim and motivation. Group work. L2 2. Role of soft-skills in researcher career. L2 3. Popular science activities. L2 4. How to learn and teach. Actualities in Physics education research. L2 5. Abstracts and their preparation. L4 6. Literature review. L2 7. Presentations and their preparation. L4 8. Current topics in physics and astronomy. S14   L - lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work will involve preparation of various deliverables for assessments (described in section "Criteria for Evaluating Learning Outcomes"). In the beginning of the course students will be introduced to principles of preparing deliverables. Consultations (both remote and in person) will be available for unclear questions. | |
| ***Requirements for Awarding Credits*** | |
| Interim assessment:  1. Popular science project - 20%  2. Pedagogical work - 20%  3. Abstract - 20 %  4. Literature review - 20%  Final assessment:  5. Exam (presentation) - 20% Students are let to the final examination only if all interim examinations are passed. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | | 1. Popular science work | x | x |  |  | x |  |  | x | | 1. Pedagogical work | x |  |  |  | x | x |  |  | | 1. Abstract | x | x | x |  | x |  | x | x | | 1. Review (Wikipedia page) | x | x | x |  | x |  | x | x | | 1. Exam (presentation) | x | x | x | x | x |  | x | x | | |
| ***Compulsory Reading List*** | |
| 1. Doumont, J., ed. English Communication for Scientists. Cambridge, MA: NPG Education, 2010 (https://www.nature.com/scitable/ebooks/english-communication-for-scientists-14053993) 2. Gabrys, B. J., Langdale, J.A. How to succeed as a scientist : from postdoc to professor. Cambridge University Press, 2012 (e-book) 3. Knight, R., Randall D. “Five easy lessons ;strategies for successful physics teaching”, ISBN 0805387021 | |
| ***Further Reading List*** | |
| 1. Bobroff, J. “Reimagining physics” Nature Nanotechnology 12, 496 (2017) 2. Bobroff, J., “Popularize Science. Why? How?“, Rīgā, 26.10.2018. https://www.facebook.com/zinatkongress/videos/201936060706749/ 3. Mazur, E. "Peer instruction : a user's manual" Prentice Hall, 1997 4. Pain, E. “How to (seriously) read a scientific paper”, Science <https://www.sciencemag.org/careers/2016/03/how-seriously-read-scientific-paper> 5. Taylor, L., A. “Twenty things I wish I’d known when I started my PhD”, Nature Carrer Column <https://www.nature.com/articles/d41586-018-07332-x> | |
| ***Periodicals and other sources*** | |
| 1. arXiv: free distribution service, open-access archive, arXiv.org 2. Google Scholar - https://scholar.google.com/ 3. Physical Review journals - https://journals.aps.org/ 4. SCOPUS - https://www.scopus.com/ 5. Web of Science – https://www.webofknowledge.com/ | |
| ***Course Content*** |  |
| 1. Introduction. Course structure, aim and motivation. Group work.  Introduction to the course and its structure. Discussion on the aim and motivation of the course. Examples of soft-skills applications. Tools for efficient group work. Tuckman model.  2. Role of soft-skills in researcher career.  Various examples of use of soft-skills for a successful research career.  3. Popular science activities.  Activities for dissemination to general public other outreach, meaning, examples. Assessment of the achievement of activity. Practical exercise.  4. How to learn and teach. Actualities in Physics education research.  Introduction to modern teaching methods in physics and technology sectors. Key elements for lesson planning. Research on the physics education. Results.  5. Abstracts and their preparation.  The importance of abstracts, the basic principles.  Practical tasks with examples of abstracts and preparation of abstracts.  6. Literature review.  Introduction to the types of scientific literature, its search and access. Scientific literature databases (Web of Science, SCOPUS, Google Scholar). Typical structure and efficient reading techniques, analysis and use of scientific articles in ones work (storage of references, systematization — Mendeley). Types of science metric (IF, SNIP, h-index), usage, relevance to the scientific environment. Copyright issue in scientific literature. Open access and open science concepts, examples and opportunities. Practical task with examples of a review of literature.  7. Presentations and their preparation.  Forms and types of presentation of scientific information, their suitability for the situation, time planning. Basic principles for creating. Practical tasks with slide examples, creating a slide, and doing an Elevator pitch  8. Current topics in physics and astronomy  Students select and visit seminars of interest in physics, astronomy and related fields. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Research laboratory works II*** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 50 |
| ***Number of Lecture Hours*** | 2 |
| ***Number of Seminar and Practical Assignment Hours*** | 0 |
| ***Number of Laboratory Work Hours*** | 48 |
| ***Independent Study Hours*** | 110 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.phys. Guntars Kitenbergs |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to promote a diverse research experience by carrying out short lab works that imitate scientific processes and provide knowledge and insights about the diverse research of physics within the laboratories and innovative companies, which was started in the course Fizi5134 Research laboratory works I.  Tasks of the course are:  1. To choose and perform laboratory works offered by research institutions and innovative companies on their respective topics;  2. To know and use different research methods, to obtain, process and interpret results;  3. To prepare a short protocol for each laboratory work and defend it by the scientist responsible for the particular laboratory work;  4. Prepare a brief in-depth presentation on the topic of one of the laboratory works performed.  Language of inscription is Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. explains selected topics in physics and astronomy, their applicability in interdisciplinary topics and understands qualitatively development of these topics;     Skills:   1. performs some research steps individually and in a group; 2. reads scientific literature about physics and astronomy, discusses it in communication with colleagues; 3. approaches complex phenomena research in an analytic way and uses various IT skills in getting, processing and interpreting data; 4. follows work safety and research integrity principles, understands the limits of own knowledge;     Competence:   1. solves physical problems, using necessary approximations; 2. performs experiments, choosing an appropriate data analysis method, error estimation and comparison with models. | |
| ***Course Plan*** | |
| 1. Introduction. Labwork list. Safety measures. Course criteria. L2 2. Labworks. Ld48   L – lecture, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| In this course students alone, in pairs or small groups have to continue working on processing, analyzing and summarizing labwork in a short report. In the beginning of the course students will be introduced to principles of performing labwork. Consultations (both remote and in person) will be available from course and labwork responsibles. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Laboratory work, preparation of reports and oral defense (number of works depends on the laboratory work selection) - 90%     Final examination:   1. Exam (oral presentation on a selected laboratory work) - 10%     Students are let to the final examination only if all interim examinations are passed. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Intermediate test | + | + | + | + | + | + | | 1. Exam | + | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Alfredo, K., Hart, H. The University and the Responsible Conduct of Research: Who is Responsible for What?, Science and Engineering Ethics, 17 (3), 447 (2011) - doi.org/10.1007/s11948-010-9217-3 2. Reviews of Modern Physics, https://journals.aps.org/rmp/ | |
| ***Further Reading List*** | |
| 1. Reports on Progress in Physics - http://iopscience.iop.org/journal/0034-4885 2. Whitbeck, C. Trust and the Future of Research, Physics Today, 57 (11), 48 (2017) - https://physicstoday.scitation.org/doi/10.1063/1.1839377 | |
| ***Periodicals and other sources*** | |
| 1. arXiv: free distribution service, open-access archive, arXiv.org 2. Physical Review journals, https://journals.aps.org/ | |
| ***Course Content*** |  |
| * + - 1. **Introduction.**   **Offer of laboratory works and their selection. Course requirements. Safety instructions.**  Introduction to course, proposed laboratory works, course organization and assignments. Safety instructions.  **2. Laboratory works.**  Students choose lab work from the proposed list. Each work has a description available in the e-study environment, including the information of the responsible scientist, the time for work execution, consultations and defense, as well as other essential information. Students agree with the responsible scientist on the work execution schedule, taking into account the availability and capacity of the laboratories. Before development, students prepare for work using the work description and the literature shown in it. The development of works takes place in pairs or larger groups, if the nature of the work requires it. For each work, students prepare a protocol, for which a substantial individual study time is allocated. Once the protocol is prepared, students defend it to the responsible scientist.  **3. Final examination. Laboratory work presentation.**  Each student chooses one of the executed lab works and prepares a brief presentation on the nature of the work, the methods used, the results and the future research challenges in that topic. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Inovations in physics and technologies*** |
|  | Physics and astronomy |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 68 |
| ***Number of Lecture Hours*** | 22 |
| ***Number of Seminar and Practical Assignment Hours*** | 46 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 92 |
| ***Course Approval Date*** | 18.03.2021 |
| ***Course Developer*** | Dr.Phys. Toms Beinerts |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to enable students to practically use scientific knowledge in the creation of practically useful innovations and technologies, and to provide basic knowledge and skills for their implementation.  Tasks of the course are:   1. To raise awareness of the importance of science and innovation in society and the skills needed for their successful implementation; 2. To learn several creative thinking and idea generation methods, as well as to practice their application in science and business; 3. To get acquainted with the business model development methodology and process, to master the formulation of a business idea about the business model process, its evaluation; 4. To learn simple methods of financial evaluation of a company or project, preparation and attraction of a finances and investments; 5. To acquire presentation skills, teamwork skills.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains the main concepts, principles and innovative management mechanisms of innovative management; 2. Understands the main orientations of theories of social behaviour, personality learning, lifestyle and innovative behaviour that promote the creation of a creative environment in the organization; 3. Understands methodology and process of business model development, its evaluation, preparation of appropriate financial model and main elements of its implementation;   Skills:   1. Visualizes the implementation of science-related projects, starting with individual research projects, to creation of science-based new enterprises and the commercialisation of technologies, including the formulation of an idea / problem, preparation and implementation of a sales plan; 2. Applicates the technique of creativity in the search for solutions to the problems as an individual or team, deepening their knowledge, skills and abilities in this field of practice;   Competence:   1. Identifies the business potential of a research or knowledge or idea, and develops an action plan for obtaining it. | |
| ***Course Plan*** | |
| 1. Role of scientists and students in commercialisation of science, innovation management and society in general. Analyses of the process of scientific activity and start-ups. L2 S2 2. Innovative process. Technology and Product Development Process, TRL. Innovative process in the management process: knowledge management. L4 S2 P2 3. Methods of Creative Thinking for Generating Ideas and Focused Tasks. Design thinking approach to product development. L3 S4 P3 4. Idea evaluation techniques. Qualitative and quantitative techniques for evaluating ideas. L2 S2 5. Conceptualizing ideas. Conceptualizing ideas with the help of a business canvas and an action map. Concept for business model development. Lean startup approach to new product development. L3 S3 P4 6. Sales and Marketing. Developing a marketing strategy for a new product. L2 S2 P2 7. Financial Planning, Project Financial Calculations. L2 P2 S2 8. Financial attraction, Public finance projects, Investments, Investment attraction, Investment readiness level, Financial risks in science projects. L2 P2 S2 9. Group / individual project development and presentation. L2 P2 S10   L – lecture, S – seminar, P - practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| 1. Formulation of a value chain for a particular student's research direction. 2. Formulating a classical 'push' innovation approach for a given or selected scientific topic project. 3. Finding a possible solution to a given or identified problem using individual and group creative thinking methods. 4. Evaluating the generated ideas using the proposed methods; choosing the optimal solution. 5. Creation of Business Canvas, Business Model, etc. of models for project work. 6. Sales Training "Games" for short marketing strategy development project work. 7. Preparation of the financial plan. 8. Identification of the most appropriate financial instruments and preparation of the financial plan for the project work. 9. Group / individual project development and presentation. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests - presentations of the work:   1. Generating Ideas - 15% 2. Business model - 15% 3. Implementation plan - 10% 4. Financial Model - 10%   Final examination:   1. Exam: Study work / project - 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | | 1. Idea generation | + |  |  | + |  | + | | 1. ﻿Bussiness model |  | + |  |  | + | + | | 1. ﻿Implementation plan |  | + | + |  | + | + | | 1. ﻿Finance model |  | + | + |  |  |  | | 1. Final exam - study work and presentation |  | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Kelley, T. The Ten Faces of Innovation. 2006 2. Osterwalder, A. Business Model Generation: A Handbook for Visionaries, Game Changers, and Challenger. 2010 3. Ries, E. The Lean Startup. How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses. 2011 | |
| ***Further Reading List*** | |
| 1. Boden, M. A. The Creative Mind: Myths And Mechanisms. Routledge 2004. 2. Chan Kim, W. Blue Ocean Strategy: How to Create Uncontested Market Space and Make Competition Irrelevan. 2006 3. Harvard Business Review. Harvard Business Essentials: Managing creativity and innovation: practical strategies to encourage creativity, Harvard Business School Press, Boston. 2003 4. Kelley, T. The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm. 2016 5. Levitt, T. Creativity is not Enough. Harvard Business Review, Harvard Business School Publishing Corporation, Boston. 2002 | |
| ***Periodicals and other sources*** | |
|  | |
| ***Course Content*** |  |
| 1. Role of scientists and students in commercialisation of science, innovation management and society in general. The world of different practices in technology transfer and innovation. Analyses of the process of scientific activity and start-ups.   Independent work: Formulation of a value chain for a particular student's research direction.   1. Innovative process. Technology and product development process. Technology readiness stages (TRL). Innovative process in the management process: knowledge management.   Individual and Group Work: Formulating a classical push innovation approach for a given or selected research topic project.   1. Creative problem solving in the organisation. Methods of Creative Thinking for Generating Ideas and Focused Tasks. Design thinking approach to product development. Creativity in the organisation. The role of the individual and the team in the innovation process.   Individual and Group Work: Finding a possible solution to a given or identified problem using individual and group creative thinking methods.   1. Idea evaluation techniques. Qualitative and quantitative techniques for evaluating ideas.   Individual and Group Work: Evaluating Created Ideas Using Proposed Methods; choosing the optimal solution.   1. Conceptualising ideas. Conceptualising ideas with the help of a business canvas and an action map. Concept for business model development. Lean startup approach to new product development   Individual and Group Work: Business Canvas, Business Model, etc. creation of models for project work.   1. Sales and Marketing. What is Sales? Sales techniques. Developing a marketing strategy for a new product   Individual and Group Work: A sales training “game” for short marketing strategy development project work.   1. Financial planning. Key financial indicators for projects and companies. Project financial indicators calculations. Drawing up of budget and cash flows.   Drawing up a financial plan.   1. Financial attraction, Public finance projects, Investments, Investment attraction, Investment readiness level, Financial risks in science projects. Practice attracting finance for innovation projects in Latvia.   Permanent and Group Work: Identifying the most appropriate financial instruments and drawing up a financial plan for the project work.   1. Group / individual project development and presentation | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Physics of informal education*** |
|  | Physics and astronomy |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 6 |
| ***Number of Seminar and Practical Assignment Hours*** | 26 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 20.04.2021 |
| ***Course Developer*** | Dr.phys. Inese Dudareva |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to develop student’s understanding of the acquisition of physics in informal education, as well as developing materials for physics lessons and developing teaching skills.  Objectives of the study course are:   1. to develop students skills to speak in front of audience; 2. to deepen students' knowledge in the development of materials for popular-science, scientific and practical physics lessons, obtaining fundamentals of content, methods and technical development of materials; 3. to develop students` skills preparing materials and explaining physics issues in a popular way according to the pupils` age; 4. to develop students` skills to prepare and carry out demonstrations in physics; 5. to develop students` skills to prepare physics olympiad tasks.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Recognizes and formulates the fundamentals of development of physics demonstrations and practical tasks;   Skills:   1. Develops teaching materials for popular-science, scientific and practical lessons in different topics of physics (V3); 2. Analyzes and creates ideas for Physics Olympiad;   Competence:   1. Successfully organizes teaching/learning process: popular-science, scientific and practical lessons in different topics of physics. | |
| ***Course Plan*** | |
| 1. The Young Physicists School organization. The fundamentals of teaching material development. L2 2. The fundamentals of teaching and lessons management. L2 3. Lesson planning in various physics topics. P2 S2 4. The skills of the teacher. L2 P2 5. Modeling of physics lesson in different topics. S6 6. Development of physics demonstration and practical tasks descriptions and the use of developed resources. P4 S4 7. The development of tests and the organization of the resources in e-environment. P2 8. Physics Olympiad task development and assessment. P4   L – lecture, S – seminar, P – practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students` independent work is organized individually.  Independent assignments:   1. Studies of the literature related to study course topics; 2. Development of teaching materials for popular-science topic (theoretical or practical) in chosen topics of physics; 3. Development or improving of Physics Olympiad tasks. | |
| ***Requirements for Awarding Credits*** | |
| Student have to develop lesson material on selected topics of the course content in physics, as well as have to carry out the Young Physicists s0chools lessons or have to participate in the Physics Olympiad task development and assessment.  Intermediate tests:   1. Development of materials for theoretical lessons – 30% 2. Development of materials for practical lessons – 30% 3. Conducted classes for students in Young Physicists school or participated in the Physics Olympiad task creation and assessment – 30%   Final examination:  4. Exam (oral) – 10% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  | | --- | --- | --- | --- | --- | | Type of Assessment | Learning Outcomes | | | | | 1. | 2. | 3. | 4. | | 1. Intermediate test Nr.1 | x | x |  | x | | 1. Intermediate test Nr.2 | x |  | x |  | | 1. Intermediate test Nr.3 | x | x |  | x | | 4. Exam | x | x | x |  | | |
| ***Compulsory Reading List*** | |
| 1. Cunningham, J., B., Herr, N. Hands-On Physics Activities with Real-Life Applications: Easy-to-Use Labs and Demonstrations for grades 8 - 12 2. Giancoli, D.C. Physics for Scientists & Engineers with Modern Physics. Pearson, 2014. 3. Knight, R.D. Five Easy Lessons: Strategies for Successful Physics Teaching. Addison - Wesley, 2004 4. Sprott, J.C. Physics Demonstrations: A Sourcebook for Teachers of Physics. University of Wisconsin Press, 2006 | |
| ***Further Reading List*** | |
| 1. Fļorovs, V., Cēbers, A., Šmits, L. Latvijas atklātā fizikas olimpiāde 1976 – 1994. Mācību grāmata, Rīga, 1995 2. Viennot., L. Thinking in Physics: the pleasure of reasoning and understanding. Springer, 2014. 3. Горшковский, В. Польские физические олимпиады. Мир. Москва, 1982 | |
| ***Periodicals and other sources*** | |
| 1. Jauno Fiziķu skola , http://jfs.lu.lv/ 2. Latvijas fizikas olimpiāžu materiāli, https://edu.lu.lv/course/index.php?categoryid=21 3. Čehijas fizikas olimpiāžu materiāli, http://fyzikalniolympiada.cz/ 4. Krievijas interneta olimpiādes, http://distolymp2.spbu.ru/olymp/ 5. Prāgas Kārļa Universitātes Fizikas un matemātikas fakultātes vietne interneta fizikas olimpiādei, http://fykos.org/ 6. Lielbritānijas fizikas olimpiādes, https://www.bpho.org.uk/ 7. Honkongas fizikas olimpiādes, https://www.hkage.org.hk/en/competitions/detail/774 8. Šveices fizikas olimpiādes, https://physics.olympiad.ch/en/ | |
| ***Course Content*** |  |
| **1. Informal Education. The Young Physicists School organization. The fundamentals of teaching material development.** (L2)  Informal Education. The Young Physicists School organization (aim, lesson structure, resources, materials in e-environment, realization). The fundamentals of teaching material development (What should be the popular science lectures? What are the practice sessions? What are the theoretical lessons? How does this relate to the content of the subject of high school physics?)  **2. The fundamentals of teaching and lessons management.** (L2)  Learning Philosophy - How do people learn at all? Why are paradigms changing and how does it apply to each of us?  How student learns – perception, thinking (nature of cognitive activity), styles, ages, their differences, learning "mechanism"... etc. How does understanding of it change as time goes by?  How does the teacher work – how does the content come to the pupil? What's the matter with? (Nature of knowledge.) When to choose (lecture, independent work ...) and when not? (When to choose to tell and when the pupil/student to do more for himself). Inductive and deductive path. Providing feedback.  **3. Lesson planning in various physics topics.** (P2, S2)  The outcomes and structure of the lesson (Initiation, awareness, reflection). Basic principles of the method of brainstorming (how to generate ideas). Principles for creating a presentation (what is a good presentation?). Practical lesson planning – popular scientific lecture in different topics of physics (in small groups).  **4. The skills of the teacher.** (L2, P2)  What is a good and what is a bad lesson? How do I understand what worked, what's not, and what to do next? What tools can help you make it a lesson appropriate for today – models, visuals, IT capabilities, etc.? What should be a good visual material and what shouldn't? Why use models and how to make sense? What should be the task the pupil/student receives? What is a good, what –  a bad task and how to transform the bad for good in teaching/learning process?  How do I run a class? Narration (lecture...). Conversation (Q&A, dialogue; how to ask and how to expect an answer, what ask...). Discussion, debate, etc. when/or choose. Working in groups (purpose, meaning, nature of the task). Presentation of group work/ independent work. Seminar/workshop based on the independent work of students/students. Project.  **5. Modeling of physics lesson in different topics.** (S6)  Modeling of prepared lesson (mini-lecture). Lesson analysis, feedback and improvement of lesson materials.  **6.** **Development of physics demonstration and practical tasks descriptions and the use of developed resources.** (P4, S4)  How can we use an experiment in science teaching? (Laboratory work, research, demonstration?). Basic principles for the preparation and demonstration of demonstrations (purpose of demonstration, visibility, the advantages and disadvantages of ICT in demonstrations). Basic principles for the preparation of practical work (objective of practical work, practical work to be carried out with simple resources).  Preparation of practical works and demonstrations in certain physics topics. Modeling of prepared demonstrations and practical works. Lesson analysis, feedback and improvement of lesson materials.  **7. The development of tests and the organization of the resources in e-environment**. (P2)  Advantages of Moodle tests. Physics Olympiad in Moodle platform. Young Physicists School materials.  **8. Physics Olympiad task development and assessment.** (P4)  The basic of Physics Olympiad tasks at various levels of Physics Olympiad stages (county stage, National stage, Open Physics Olympiad). | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Microscopy methods*** |
|  | Chemistry |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 8 |
| ***Number of Seminar and Practical Assignment Hours*** | 4 |
| ***Number of Laboratory Work Hours*** | 20 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 10.10.2016 |
| ***Course Developer*** | Dr.chem. Donāts Erts |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to provide students with the understanding of scanning and transmission electron microscopy, energy dispersive X-ray spectroscopy and scanning atomic force microscopy.  Tasks of the course are:   1. To gain knowledge on the principles, design and practical application of the equipment. 2. In practical classes, to learn to work with equipment at a level that would give the right to use it independently.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands the principles, structure and applications of scanning and transmission electron microscopy; 2. Explains the principles and applications of energy dispersive X-ray spectroscopy; 3. Explains the principles, structure and applications of scanning tunnel and atomic microscopy;   Skills:   1. Works with information flow on microscopy methods; 2. Presents the obtained results, discuss the principles of operation, construction and practical applications of equipment; 3. Operates the equipment at their user level;   Competence:   1. Applicates equipment for practical measurements; 2. Explains the results obtained; 3. Advises and explains interested parties scanning and transmission electron microscopy, energy dispersive X-ray spectroscopy and scanning atomic force microscopy. | |
| ***Course Plan*** | |
| 1. Scanning and transmission electron microscopy. L4 Ld6 S2    1. Principle, Structure and Applications of Scanning Electron Microscopy    2. Transmission Electron Microscopy 2. Energy dispersive X-ray spectroscopy (EDS). L2 Ld6 S2 3. Atomic force microscopy L4 Ld8 S2    1. Scanning tunneling microscopy and spectroscopy    2. Scanning atomic force microscopy and spectroscopy    3. Scanning near field optical microscopy    4. Scanning electrochemical microscopy   L – lecture, Ld – laboratory work, S - seminar | |
| L - lecture, S - seminar, P - practical work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' individual work is organized individually and / or in groups for the following tasks: processing and analyzing the results of laboratory work, preparing presentations on laboratory work, preparation for seminars, mid-term examinations and examinations. | |
| ***Requirements for Awarding Credits*** | |
| Participation in the practical laboratory work and seminars is compulsory.  Intermediate tests / practical work / laboratory work:   1. Intermediate test / LD1 - 10% 2. Intermediate test / LD2- 10% 3. Intermediate test / LD3 - 10% 4. Practical work and its defense PD1 - 15% 5. Practical work and its defensePD2 - 15% 6. Practical work and defense PD3 - 15%   Final examination:   1. Exam (written) - 25% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | | 1. Intermediate test LD1 | x |  |  | x | x | x |  | x | X | | 1. Intermediate test LD2 |  | x |  | x | x | x |  | x | X | | 1. Intermediate test LD3 |  |  | x | x | x | x |  | x | X | | 1. Practical work PD1 | x |  |  | x |  | x | X |  |  | | 1. Practical work PD2 |  | x |  | x |  | x | X |  |  | | 1. Practical work PD3 |  |  | x | x |  | x | x |  |  | | 1. Exam | x | x | x | x | x | x | x | x | x | | |
| ***Compulsory Reading List*** | |
| 1. Bell, D.C. Energy Dispersive X-ray Analysis in the Electron Microscope. Routledge; 1 edition, 2003 2. Goldstein, J., Newbury, D E., Joy, D C., Lyman, C.E., Echlin, P., LIfshin, E., Sawyer, L., Michael, J.R. Scanning Electron Microscopy and X-ray Microanalysis, 3rd ed. 2003, 586p. 3. Lecture materials (e-course, 2015) 4. Wiesendanger, R. (ed.) Scanning Probe Microscopy and Spectroscopy. Cambridge, University Press. 1994 5. Williams, D.B., Carter, C.B.Transmission Electron Microscopy. Springer, 2nd edition, 2009 | |
| ***Further Reading List*** | |
| 1. Sheppard, C.J.R., Shotton, D.M. Microscopy and Analysis Probe Microscopes: Applications in Science and Technology. Published by: CRC Press. 2002 2. Wiesendanger, R. (ed.) Scanning Probe Microscopy: Analytical Methods Springer Series Nanoscience and Technology, Springer. 1998 | |
| ***Periodicals and other sources*** | |
| 1. Science Direct, <https://www.sciencedirect.com> 2. Springer, https://www.springer.com/ 3. Wiley Analytical Science: Latest Spectroscopy Articles, www.spectroscopynow.com | |
| ***Course Content*** |  |
| **Theme 1. Scanning electron microscopy SEM.**  (lectures - 4 hours, laboratory works - 6 hours, seminar - 2 hours)  Electron microscopy and electron microscope operation principles. Electron microscope magnification and resolution control. Detectors for use in electron microscopes, regulation of their resolution. Electron microscope images and their aberrations. Software for electron microscopy and its use for image editing and measurement. Sample preparation for SEM studies. Electron microscope compatible with focused ion beam equipment, principle, design and applications.  Laboratory work and its defense in a seminar  1.2. Principles, structure, applications of transmission electron microscopy. Scanning transmission electron microscopy. Electron Energy Loss Spectroscopy (EELS). Preparation of samples for TEM studies.  **Theme 2. Energy dispersive X-ray spectroscopy (EDS)**  (lectures - 2 hours, laboratory works - 6 hours, seminar - 2 hours)  Principles of EDS operation, regulation of EDS, provision of EDS programs, obtaining, processing and interpretation of results.  Laboratory work and its defense in a seminar  **Theme 3. Scanning probe microscopy.**  (lectures - 4 hours, laboratory works - 8 hours, seminar - 2 hours)  Principles of operation of scanning tunneling microscope, atomic force microscope, scanning near-field optical microscope and scanning electrochemical microscope. Application of microscopes for characterization of topography of surfaces, determination of electron structure, conductivity, interaction of forces, determination of optical and other properties Preparation of microscope for work, replacement of needles, obtaining of their characteristic parameters. Measurements of topography, force interactions and others. Software for atomic force microscopy, its use for obtaining and processing results. Interpretation of results. Laboratory work and its defense in a seminar | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Modern methods in surface and colloid chemistry*** |
|  | Chemistry |
| ***Number of Seminar and Practical Assignment Hours*** | 4 |
|  | 64 |
|  | 12 |
|  | 12 |
| ***Number of Laboratory Work Hours*** | 40 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 25.01.2019 |
| ***Course Developer*** | Dr.chem. Guntars Vaivars |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The goal of the course is to teach students the theoretical and practical aspects of surface and colloidal chemistry. In practical students will become familiar with traditional and modern methods to produce and characterize colloidal systems and surfaces and extend their theoretical knowledge.  The tasks of the course are:   1. acquire basic knowledge, skills and competences about chemical and physical processes in surface; 2. acquire basic knowledge, skills and competences about chemical and physical processes in colloidal systems.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains theoretical principles and practical application of colloidal systems and surface phenomena in chemistry; 2. Describes surface phenomena relation with the properties of colloidal systems; 3. Understands the usage of micellas and other colloidal systems in a pharmaceutical chemistry;   Skills:   1. Selects and applicates basic colloidal system characterization methods; 2. Operates the Excel Solver for adsorption isotherm calculation; 3. Applies the geometric parameter measurements to characterizes the micelle structure;   Competence:   1. Assesses the modern colloidal system characterization methods and its usage in Latvian research institutions in solving practical colloidal system problems in a pharmaceutical chemistry and other industries. | |
| ***Course Plan*** | |
| 1. Colloid chemistry in general. Specific of disperse systems and classification. L2 2. Molecular kinetic properties of colloidal systems. Ld4 3. Optical and electrical properties of colloidal systems. L4 Ld8 4. Surface chemistry. L4 Ld8 5. Colloidal systems – producing and stability. Ld8 6. Modern investigation methods of colloidal systems. L2 Ld12 S8   L - lecture, S - seminar, P - practical work, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is organized on individual basis and / or small working groups by signing the following tasks: to prepare independently for seminars and intermediate examinations, to study literature on related topics, prepare laboratory reports and perform calculation exercises. | |
| ***Requirements for Awarding Credits*** | |
| Participation in the practical laboratory work and lectures is compulsory.  Intermediate tasks:   1. Laboratory work - 45% 2. Test Nr.1 - 10% 3. Test Nr.2 – 10%   Final examination:   1. Exam (written) - 35% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | | 1. Laboratory work | x | x | x | x | x | x | x | | 1. Test Nr.1 | x | x |  |  |  |  | x | | 1. Test Nr.2 |  |  | x | x |  |  | x | | 1. Exam | x | x | x | x | x | x | x | | |
| ***Compulsory Reading List*** | |
| 1. Cosgrove, T. Colloid science: principles, methods and applications, 2nd Edn., Wiley, 2010, 375 p. (LUB pieejama e-grāmata). 2. Pashley, R. Applied colloid and surface chemistry. England, Wiley, 2004., 188 lpp. (LUB 4 eks.) 3. Ross, S., Morrison, I.D. Colloidal systems and interfaces. New York, Wiley, 1988. (LUB 1 eks.) | |
| ***Further Reading List*** | |
| 1. Atkins, P., de Paula, J. Atkins’ Physical Chemistry. 8th Ed., Oxford, University-Press, 2006, 1064 lpp. (LUB 27 eks. + 30 ekJs. 7th Edn.). 2. Birdi, K.S., Surface and colloid chemistry : principles and applications. CRC Press, 2010, 244 p. 3. Engel, T., Reid, P. Physical Chemistry, 3rd Edn., Pearson Education, 2014, 1040 p. 4. Garland, C.W., Nibler, J.W., Shoemaker, D.P. Experiments in Physical Chemistry, 7th Edn., McGraw-Hill, 790 p. 5. Halpern, A.M., McBane, G.C. Experimental physical chemistry: a laboratory textbook. New York: Freeman, 2006, 3rd ed. Part 5. (LUB 1 eks) 6. Schwenz, R.W., Moore, R.J. Physical Chemistry.-Washington: American Chemical Soc., 1993. (LUB 11 eks.) 7. Singh, J.K., Verma, N. Aqueous Phase Adsorption: Theory, Simulations and Experiments. 1st ed. 2018. CRC Press. ISBN 9781138575219. 8. West, A. Basic solid state chemistry. 2nd ed. Wiley & Sons, 2008. p.261-292. (LUB 1 eks.) | |
| ***Periodicals and other sources*** | |
| 1. Journal of Colloid and Interface Science 2. Shaw, D.J. Colloid and surface chemistry. 4th Ed. 1992. http://cnqzu.com/library/Anarchy%20Folder/Chemistry/MISC/Intro%20to%20Colloid%20&%20Surface%20Chemistry%20(Duncan-Shaw).pdf [skatīts 02.04.2016] 3. The Journal of Physical Chemistry | |
| ***Course Content*** |  |
| **1. topic**. **Colloid chemistry in general. Specific of disperse systems and classification.**  Lectures – 2 hours  1.lecture. Colloidal chemistry as a branch of physical chemistry and as a study subject. Classification of disperse systems- phase, environment, dispersion. Surface energy. Colloidal systems for producing innovative materials.  Thermal equilibrium (osmosis, diffusion) and Brownian motion. Particle shape. Einstein -Smoluchowski theory. The mean squared displacement of a Brownian particle and the diffusion coefficient. Stokes- Einstein equation. Perrin, Svedberg and Soddy experiments. Avogadro number. Sedimentation velocity and Stokes equation. Viscosity. Sedimentation analysis. Osmotic pressure of colloidal systems. Einstein equation. Determination of molar mass. Ultracentrifuge.  **2. topic**. **Molecular kinetic properties of colloidal systems**.  Practical – 4 hours.  Practical. Sedimentation analysis.   **3. topic.** **Optical and electrical properties of colloidal systems**.  Lecture – 4 hours, practical – 8 hours.  2. lecture. Optical properties of disperse systems. Light dispersion and absorption, and its dependence on particle sizes and wavelength. Light dispersion in atmosphere. Turbidimetry.  3. lecture. Electrical properties of disperse systems. Electrical double layer on phase interfaces. Potential distribution. Electrokinetic phenomena of disperse systems. Electrophoresis, electro-osmosis, flow potential. Electrophoresis as a research method. Electrophoretic mobility. Zonal electrophoresis. Helmholz-Smoluchowski equation. Methods and equipment for obtaining zeta potential. Practical applications of zeta potential measurements.   2. practical. Electroosmosis – 4 hours.  3. practical. Elektrophoresis – 4 hours.   **4. topic**. **Surface chemistry**.  Lecture – 4 hours, practical – 8 hours, seminar – 4 hours.  4. lecture. Specific surface and particle dimensions. Surface tension and its measuring methods. Adsorption. Surface active substances (surfactants). Traube’s rule. Surfactants and micelles. Detergents. Critical concentration. Micelle formation. Gibbs adsorption equation. Surface activity.  5.lecture. The Langmuir, Freundlich and BET adsorption models. Capillary condensation. Aging. Ostwald ripening.  1.seminar. Adsorption isotherms (Excel Solver).   4. practical. Adsorption on carbon– 4 hours.  5. practical. Surface tension isotherms– 4 hours.   **5. topic.** **Colloidal systems – producing and stability.**  Practicals – 8 hours.  Disperse system synthesis. Condensation and dispersion methods. The Rehbinder effect. Aggregation kinetics and colloidal stability. Stability control strategies. Coagulation and coagulation theories. The Schulze-Hardy rule.  6. practical. Disperse systems- synthesis and stability.  7. practical. Coagulation kinetics.   **6. topic.** **Modern investigation methods of colloidal systems**.  Lecture – 2 hours, seminars – 8 hours, practicals – 12 hours.  6. lecture. Modern colloidal system characterization methods. Surface Plasmon Resonance Spectroscopy. Isothermal titration calorimetry.  2. seminar. Particle size distribution in micelles.  3. seminar. Langmuir–Blodgett method.  8. practical. Preparation of pharmaceutical micelles.  9. practical. Particle size distribution in micelles.  10. practical. Langmuir–Blodgett method- obtaining micelle diameter. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| --- | --- |
| ***Study Course Title*** | ***Quantum Computers*** |
|  | Computer science |
| ***Credits*** | 2 |
| ***Total Number of Contact Hours*** | 32 |
| ***Number of Lecture Hours*** | 32 |
| ***Number of Seminar and Practical Assignment Hours*** | 0 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 48 |
| ***Course Approval Date*** | 01.03.2018 |
| ***Course Developer*** | Dr.habil.math., Rūsiņš Mārtiņš Freivalds |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to introduce students to the basics of quantum computation.  Tasks of the course are:   1. learn the formalism of quantum computation: qubits and operations on them; 2. understand the most popular quantum algorithms: Shor’s algorithm for discrete logarithm and integer factorisation and Grover’s algorithm for unstructured search.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands the formalism of quantum computation and its basic elements; 2. Understands basic quantum algorithms;   Skills:   1. Analyzes behaviour of a quantum algorithm; 2. Constructs quantum algorithms that are based on quantum search and quantum Fourier transform;   Competence:   1. Critically analyses and evaluates the class of problems that are effectively solvable by a quantum computer. | |
| ***Course Plan*** | |
| 1. Quantum bits. L2 2. Operations on quantum bits. L2 3. Quantum circuits. L2 4. Introduction to quantum cryptography. L2 5. Entanglement. L2 6. Quantum non-locality. L2 7. The formalism of quantum algorithms. L2 8. Simple quantum algorithms. L2 9. Quantum search. L4 10. Quantum amplitude amplification. L2 11. Quantum Fourier transform. L2 12. Shor’s algorithm. L4 13. Density matrices. L4   L – lectures | |
| ***Characterization of students' independent work organization and tasks*** | |
| During the lectures the theoretical material will be presented, and it will be illustrated with examples. While solving the assignments the students will have to solve problems similar to the examples considered in class. There will be some advanced problems, to solve them the student will have to demonstrate a deeper understanding of the material. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. Assessment work – 20% 2. Homework – 20% 3. Home work – 20%   Final examination:   1. Exam (combined) – 40%   Regularly, every week the given homework must be completed. Homework is graded twice – during each of the assessment works.  The total course grade is calculated by the formula (M1+M2+P1+2\*P2)/5, where P1, P2 – grades received for the assessment works; M1, M2 – grades for homework received at the moments of assessment work. Minimum grade 4 must be achieved.  Grade 10 can be achieved by perfect solving of an individual assignment. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  For the assignments and the final exam the correctness of the turned in solutions will be evaluated.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | 1. | 2. | 3. | 4. | 5. | | 1. Assesment work | + | + | + | + | + | | 2. Homeworks | + | + | + | + | + | | 3. Exam | + | + | + | + | + | | |
| ***Compulsory Reading List*** | |
| 1. Kitaev, A.Y., Shen, A.H., Vyalyi, M.N. Classical and Quantum Computation. American Mathematical Society, 2002 2. Nielsen, M.A., Chuang, I.L. Quantum Computation and Quantum Information. Cambridge University Press, 2000 3. Parthasarthy, K. R. Lectures on Quantum Computation, Quantum Error Correcting Codes And Information Theory. American Mathematical Society, 2005 | |
| ***Further Reading List*** | |
| 1. Bracewell, R.N. The Fourier Transform & Its Applications. McGraw-Hill, 1999 2. Burda, I. Introduction to Quantum Computation. Universal Publishers, 2005 3. James, J. F. A Student's Guide to Fourier Transforms. 2nd edition. Cambridge University Press, 2002 | |
| ***Periodicals and other sources*** | |
| 1. Prof. Umesh V. Vazirani: Selected Courses, http://www.cs.berkeley.edu/~vazirani/#courses | |
| ***Course Content*** |  |
| 1.  Quantum bits  Deterministic, randomized and quantum computational modes.  Deterministic, randomized and quantum bits.  2. Operations on quantum bits  Unitary transformations, sequential composition of quantum operations, measurements.  3. Quantum circuits  Qudits, operations on several qubits, parallel composition of quantum operations, partial measurement.  4. Introduction to quantum cryptography  BB84 protocol and its analysis.  5. Entanglement  Entanglement, its physical role, EPR pair.  Quantum teleportation.  6. Quantum non-locality  CHSH game and its physical consequences.  7. The formalism of quantum algorithms  How quantum algorithms compute functions, quantum input oracles.  Transforming a randomized algorithm into a quantum one.  8. Simple quantum algorithms  Quantum algorithms that use few qubits.  Quantum search on 4 elements.  9. Quantum search  Grover’s search and its analysis.  Non-trivial application of Grover’s search, minimum finding.  10. Quantum amplitude amplification  Quantum amplitude amplification as a generalization of Grover’s algorithm.  Its applications, element distinctness problem.  11. Quantum Fourier transform  Definition of quantum Fourier transformation.  Its effective implementation on a quantum computer.  12. Shor’s algorithm  Shor’s algorithm for finding the period: the special and the general cases.  Its applications: computing discrete logarithm, integer factoring.  13. Density matrices  Ensembles of quantum states, density matrices.  Operations on density matrices: unitary transformations and measurements. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Spectrometric Analysis*** |
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| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 28 |
| ***Number of Seminar and Practical Assignment Hours*** | 20 |
| ***Number of Laboratory Work Hours*** | 16 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 29.03.2019 |
| ***Course Developer*** | Dr.chem. Andris Actiņš  Dr.chem. Vadims Bartkevičs  Dr.chem.asoc. Anda Prikšāne  Mg.chem. Zenta Balcerbule |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the study course is to create knowledge and develop students' understanding of modern spectrometric analysis methods.  The tasks of the study course are:   1. to get acquainted with the differences between spectrometric analysis methods; 2. to get an insight into the selection of the appropriate analytical procedure for characterizing a specific sample; 3. to learn to solve problem situations related to spectrometric measurements; 4. to analyze the suitability of the acquired methods for scientific research needs; 5. to gain an experience to practically implement spectrometric methods for solving of experimental tasks.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Explains theoretical principles and application possibilities of modern spectrometric methods; 2. Describes current trends in development of spectrometric methods;   Skills:   1. Selects appropriate spectrometric analysis methods for solving sophisticated laboratory questions; 2. Applies, optimizes and validates spectrometric methods for environmental object, food and pharmaceutical sample analysis; 3. Compares the applicability of different spectrometric methods (UV, fluorimetry, Raman, etc.); 4. Uses scientific publications and reference literature for selection of spectrometric methods and optimization of parameters; 5. Creates presentations and reports on the choice and applicability of spectrometric methods;   Competence:   1. Analyzes literature data and applies complex spectrometric methods for detecting chemical substances in different objects. | |
| ***Course Plan*** | |
| 1. Overview of modern spectrometric methods. L4 2. Ultraviolet and visible spectrum (UV / VIS) spectrometry: theoretical principles and applications. L4 S4 3. Modern equipment for molecular spectroscopic analysis. L4 S4 4. Raman spectrometry. L4 5. Simultaneous determination of two or more light absorbing compounds. Ld8 6. Application of spectrometric methods for analysis of chemical compounds. S4 Ld6 7. Atomic absorption spectrometry. Flame atomization. L2 8. Atomic absorption spectrometry. Electrothermal atomization. L4 9. Factors influencing the background in atomic absorption spectrometry. L2 10. Solving the tasks and challenges in atomic absorption spectrometry. S4 11. Theoretical principles of molecular luminescence. L2 12. Applications of molecular luminescence. L2 13. Solving the tasks and challenges in fluorimetry, analysis of the results. S4 Ld2   L – lecture, S – seminar, Ld – Laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| During their independent work students prepare a report on selected topics, read literature on issues discussed during lectures, prepare reports on the progress of laboratory work. | |
| ***Requirements for Awarding Credits*** | |
| Participation in the practical laboratory work and seminars is compulsory.  Intermediate tests:   1. Laboratory works - 20% 2. 3 intermediate tests (molecular spectrometry, atomic absorption spectrometry, fluorimetry)- 30% 3. a report and and its’ presentation - 10%   Final examination:   1. Exam (written) - 50% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | | 1. Test No.1 | x | x | x |  | x | x |  | x | | 1. Test No.2 | x | x | x |  | x | x |  | x | | 1. Test No.3 | x | x | x |  | x | x |  | x | | 1. Laboratory work | x |  | x | x |  | x | x | x | | 1. Seminar presentations | x | x | x | x | x | x | x | x | | 1. Exam | x | x | x | x | x | x | x |  | | |
| ***Compulsory Reading List*** | |
| 1. Broakaert, J.A. Analytical Atomic Spectrometry with Flames and Plasma. 2nd edition, Wiley-VCH, Weinheim, 2005 2. Haries, D.C. Quantitative chemical Analysis, 9th edition. 2015 3. Skoog, A.D. (ed.) Fundamentals of analytical chemistry, 9th edition. 2013 4. Skoog, D.A., Holler, F.J., Crouch, S.R. Principles of instrumental analysis. 7th edition, 2017, Cengage Learning | |
| ***Further Reading List*** | |
| 1. Actiņš, A., Balcerbule, Z..E-kurss Spektrometriskās analīzes metodes. 2006 2. Camman, K. Instrumentelle Analytische Chemie. Spektrum Akademischer Verlag, GmbH, Heidelberg-Berlin, 2001 3. Cullen, M. (ed.) Atomic Spectroscopy in Elemental Analysis. Blackwell Publishing Ltd, USA-Canada, 2004 4. Dean, J.R. Atomic Absorption and Plasma Spectrosopy. John Wiley & Sons, Chichester, 1997 5. Helmut, G., Wiliams, A. Handbook of Analytical Techniques. 2002 6. IR and Raman Spectroscopy, Siegfried Wartewig, 2003 7. Keller, R. Analytical Chemistry. Wiley-VCH Verlag, 2nd edition, 2004 8. Meyers, R. (ed.) Encyclopedia of Analytical Chemistry, 2000 9. Potts, P.J., West, M. (ed.) Portable X-ray Fluorescence Spectrometry.Capabilities for In Sity Analysis, 2008 10. Smith, E., Dent, G. Modern Raman Spectroscopy, A Practical Approach. 2nd edition, Wiley, 2018 | |
| ***Periodicals and other sources*** | |
| 1. Žurnāli: Spectochimica Acta, TrAC-Trends in Analytical Chemistry, Analytical Chemistry 2. Wiley Analytical Science: Latest Spectroscopy Articles, www.spectroscopynow.com | |
| ***Course Content*** |  |
| **General overview of the modern spectrometric techniques** (Lecture – 4 h)  Subdivision of modern spectrometric methods depending on the electromagnetic spectrum part involved in the measurement process. Equations describing the characteristics of electromagnetic radiation. Interaction of radiation with chemical compounds - light absorption, scattering, reflection. Elemental energetic levels and sublevels, possible (allowed) electron transitions and their probabilities. Electron transition charts. Absorption dependence on the applied radiation power. Excited electron deactivation and relaxation processes in molecules. Light emission. The use of the Beer-Lambert Law and the deviations from the law.  **Theoretical principles and applications of ultraviolet and visible range (UV/VIS) spectrometry** (Lecture – 4 h)  Selection of energy carriers in ultraviolet and visible spectrum (UV/VIS) spectrometry, their specific effects. UV/VIS spectrometers, their operating principles, advantages and disadvantages. UV/VIS spectrum qualitative interpretation and their use in analytical chemistry. Factors affecting molecular absorption. Spectrometer calibration, UV/VIS spectrum catalogs. Calculation of calibration constants. The applications of the UV/VIS method for the determination of chemical compounds. Special modifications of the UV/VIS methods: flow photometry, ELISA. Light reflection, application of nephelometry and turbidimetry.  **Modern equipment used for performance of molecular spectrometric measurements** (Lecture – 4 h)  Review of modern spectrometric equipment. Recent trends in the design of light sources, monochromatic systems, their characteristics. Spectrometers manufacturers and their characteristics. Spectral resolution. Characterisation of resolution capabilities with atomic and molecular spectra. The effect of the resolution capability on the shape of the peak. Wavelength stability. Impact of diffused light. Drift impact. Photon detectors, their characteristics. Multichannel detectors. Use of molecular spectrometry to detect the signal in liquid chromatography.  **Raman spectrometry** (Lecture – 4 h)  Theoretical principles of Raman spectrometry. Scattering of electromagnetic radiation. Obtaining and interpreting Raman spectra, Stokes and anti-Stokes bands, their formation. Laser as a source of radiation. Raman spectrometry comparison with other spectroscopic methods.  **Atomic absorption spectrometry. Flame atomization** (Lecture – 2 h)  Absorption and emission transition of electrons in flame. Physical and chemical processes in the flame. Different techniques of atomization and excitation. Radiation sources. Composition of the gas mixture. Analytical factors influencing the analysis. Flame atomic absorption spectrometry applications in analytical chemistry.  **Atomic absorption spectrometry. Electrothermal atomization**(Lecture – 4 h)  Electrothermal atomizers. Graphite furnaces. Sample introduction. Analysis of solid samples. The factors influencing the analytical results, the choice of atomization temperature. Graphite oven program optimization. Electrothermal atomic absorption application in analytical chemistry. Comparison of flame and electrothermal atomization.  **Interfering factors in atomic absorption spectrometry** (Lecture – 2 h)  Interfering factors in atomic absorption spectrometry, their elimination possibilities. Background correction in atomic absorption spectrometry - deuterium, Zeeman correction. Comparison of different background correction methods. Use of different background corrections in the field of food and environmental atomic absorption measurements  **Theoretical principles of molecular luminescence spectrometry** (Lecture – 2 h)  The development of molecular fluorescence, their theoretical principles. Fluorescence phenomenon, equations describing the analytical technique. Stocks shift, the relation of fluorescence spectra to energy levels. Fosforescence. Hemiluminescence. Quantitative fluorimetry. Advantages of the method. Factors influencing intensity of fluorescence.  **Applications of molecular luminescence spectrometry**(Lecture – 2 h)  Applications of fluorimetric methods in biochemistry, analysis of food products, studies on environmental pollution. Determination of vitamins, aflatoxins and polycyclic aromatic hydrocarbons by fluorimetric method. Calibration of equipment, interfering factors in fluorimetry. Phosphorescence applications. Use of "time-domain" and "frequency-domain" fluorimetry in biochemistry.  **Theoretical principles and applications of UV/VIS spectrometry** (Workshop – 4 h)  The workshop is intended for discussion on the application of UV / VIS spectrometry for the determination of chemical compounds. Each student should prepare information on the use of UV / VIS spectrometric methods for determining the quantitative content of a substance, justify the parameters of the method, report the advantages and disadvantages of the analysis.  **Modern equipment for molecular spectrometric measurements** (Workshop – 4 h)  Seminar topics: Simultaneous determination of two or more light absorbing substances in solution. Determination of pKa parameter for indicators. Principal structure of optical equipment, specific characteristics, measurement of spectra by spectrophotometer PerkinElmer Lambda25. Flame photometry. Photometric titration. Tasks.  **Spectrometric methods for determination of chemical compounds**(Workshop – 4 h)  Seminar topics: differential photometry, extraction photometry, concentration of the detectable substance. Standard and standard addition methodologies. Calibration curve. Sensitivity, repeatability and precision of photometric methods. Measurement quality characteristics. Computation of the detection level and the lowest detectable concentration. Tasks. Test work.  **Tasks in atomic absorption spectrometry**(Worshop – 4 h)  Analysis of the heavy metal content with a flame atom absorption spectrometer Analyst 200 (manufacturer Perkin Elmer). Tasks. Test work.  **Tasks in fluorometry** (Workshop – 4 h)  The workshop is devoted to discussions on the use of molecular luminescence spectrometry for the determination of chemical compounds. Each student has to prepare information on the use of fluorimetric or phosphorescence methods for the determination of a chemical compounds, to justify the parameters of the method, to report the advantages and disadvantages of the analysis.  **Possible selection of the practical tasks:**  *1st task.* Photometric determination of protolysis contanct for two colour indicator (4 h)  *2nd task.* Photometric determination of Cr(III) and Mn(II) ions in one solution (4 h)  *3rd task*. Analysis of alloys. Differential photometric determination of nickel ions (4 h)  *4th task.* Standard addition method for determination of Fe(III) ions (2 h)  *5th task.* Fluorimetric analysis of food or environmental contaminant (2 h)  *6th task*. Photometric titration of Mg (4 h)  *7th task*. Extraction photometric determination of Cu (II) ions (4 h)  *8th task*. Fluorimetric analysis of benzo(a)pyrene and chrysene in one solution (2 h) | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | **Physical Chemistry** |
|  | Chemistry |
| ***Credits*** | 4 |
| ***Total Number of Contact Hours*** | 64 |
| ***Number of Lecture Hours*** | 22 |
| ***Number of Seminar and Practical Assignment Hours*** | 26 |
| ***Number of Laboratory Work Hours*** | 16 |
| ***Independent Study Hours*** | 96 |
| ***Course Approval Date*** | 27.01.2019 |
| ***Course Developer*** | Dr.ķīm. Agris Bērziņš |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of this course is to give an insight into description of chemical systems and reactions using computational chemistry approach.  The tasks of the course are:   1. to identify the basic principles of statistical thermodynamics; 2. to extend knowledge in use of methods of thermodynamics for description of chemical systems and reactions; 3. to get acquainted with computational chemistry methods and their applications; 4. to learn how to select the most appropriate computational chemistry method and perform molecular modelling to calculate the physico-chemical characteristic of interest; 5. to learn how to analyze and interpret results obtained in the molecular modelling in connection with physico-chemical characteristics of molecules and chemical reactions.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands the concepts of statistical thermodynamics and the relation between the structure of matter and the macroscopic thermodynamic properties; 2. Describes different methods of computational chemistry, their basic concepts, possibilities and limitations; 3. Understands characteristics and properties which can be calculated or simulated using the methods of computational chemistry as well as their potential use;   Skills:   1. performs calculation of different thermodynamic parameters as well as evaluates adequacy and further use of the obtained results; 2. chooses what calculations have to be performed to determine the physical property of interest or to find the necessary characteristic of the chemical system; 3. selects the most appropriate method of quantum chemical calculations for the problem of interest;   Competence:   1. selects the most appropriate method for numerical calculation of thermodynamic property; 2. composes the input data and practically carries out quantum chemical calculations at various computation levels by obtaining the necessary results, as well as evaluates and interpret data obtained in the calculations; 3. analyzes self-acquired and in the scientific literature published computational results, discusses their accuracy, alternative computational methods, as well as justifies selected computational method. | |
| ***Course Plan*** | |
| 1. Statistical thermodynamics and on its foundations based chemical thermodynamics and kinetics. L8 S8 2. Concepts of computational chemistry their relation to chemical transformations. L2 S4 3. Methods of computational chemistry. L8 S4 4. The use of computational chemistry for solution of chemistry related problems. L4 S10 Ld16   L - lecture, S - seminar, P - practical work, Ld – laboratory work | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is organized on individual basis and / or small working groups by assigning the following tasks: to prepare independently for seminars and intermediate examinations; to study literature on related topics, prepare laboratory reports and perform calculation exercises. | |
| ***Requirements for Awarding Credits*** | |
| Intermediate tests:   1. 3 practical tasks in thermodynamics and 4 practical tasks in computational chemistry - 30% 2. Seminar: literature analysis report and presentation - 5% 3. Laboratory works - 30%   Final examination:   1. Exam (written) - 35% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| Evaluation of the student work is carried out in accordance to the Cabinet of Ministers Regulation No. 240 (13 May 2015) in a ten-point system, according to these criteria: volume and quality of the knowledge earned; skills acquired; competencies according to the study results planned.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | | 1. Practical tasks | x | x | x | x | x | x | x | X |  | | 1. Laboratory works |  | x | x | x | x | x |  | x | x | | 1. Seminair |  | x |  |  | x | x |  | x | x | | 1. Exam | x | x | x | x | x | x | x | x | x | | |
| ***Compulsory Reading List*** | |
| 1. Atkins, P., de Paula, J. ATKINS’ Physical chemistry, 11th edition, Oxford, University Press, 2018 2. Cooksy, A. Physical Chemistry. Thermodynamics, Statistical mechanics, & Kinetics, Boston, Pearson, 2013 3. Foresman, J.B., Frisch, A. Exploring Chemistry With Electronic Structure Methods, 3rd edition, CT, Gaussian, Inc., 2015, 302 p. 4. Lewars, E.G. Computational Chemistry. Introduction to the Theory and Applications of Molecular and Quantum Mechanics, second Edition, London, Springer, 2011, 664 p. | |
| ***Further Reading List*** | |
| 1. Bachrach, S.M. Computational Organic Chemistry, New Jersey, John Wiley & Sons, 2007, 478 p. 2. Hehre, W.J. A Guide to Molecular Mechanics and Quantum Chemical Calculations, Irvine, CA, Wavefunction, Inc., 2003, 796 p. 3. Hinchliffe, A. Molecular modelling for beginners, 2nd edition, Wiltshire, Wiley, 2008, 411 p. 4. Jensen, F. Intoduction to Computational Chemistry, 2nd edition, London, John Wiley & Sons, 2007, 600 p. 5. Levine, I.N. Quantum chemistry, 7th edition, Boston, Pearson, 2014, 700 p. 6. McQuarrie, D.A. Quantum chemistry, 2nd edition, Sausalito, CL, University Science Books, 2008, 690 p. | |
| ***Periodicals and other sources*** | |
| 1. Computational and Theoretical Chemistry 2. Journal of Chemical Theory and Computation 3. Journal of Computational Chemistry 4. The Journal of Physical Chemistry | |
| ***Course Content*** |  |
| **Topic 1**  **Statistical thermodynamics and on its foundations based chemical thermodynamics and kinetics. L8 S8**  Lecture 1 and Seminar 1. Repetition of fundamentals of thermodynamics and quantum mechanics. Introduction to statistical thermodynamics. Boltzmann's entropy formula and Gibbs entropy. Canonical ensemble and canonical partition function.  Lecture 2 and Seminar 2. Degrees of freedom. Equipartition theorem. Vibration and rotation partition functions. Translational partition function. Entropy and internal energy. Heat capacity.  Lecture 3 and Seminar 3. Reaction energy surface and reaction coordinate. Calculation of reaction enthalpy, entropy and Gibbs energy. Chemical equilibrium and its temperature dependence.  Lecture 4 and Seminar 4. Rate of chemical reactions. Simple collision theory. Transition state theory. Eyring equation.  **Topic 2**  **Concepts of computational chemistry their relation to chemical transformations. L2 S4**  Lecture 5. Concepts of computational chemistry. Potential energy surface. Molecular mechanics.  Seminar 5. Potential energy surface and its analysis.  Seminar 6. Transition states and their modelling.  **Topic 3**  **Methods of computational chemistry. L8 S4**  Lecture 6. Hückel method, its use and limitations. Extended Hückel method.  Lecture 7. Hartree–Fock method. Variational method and its use in Hartree–Fock method. Molecular orbitals as linear combination of atomic orbitals. Basis set.  Lecture 8. Electron correlation problem. Post-Hartree–Fock method. Perturbation theory methods. Configuration interactions methods.  Lecture 9. Density functional theory and its use in quantum chemical calculations. Semiempirical methods.  Seminar 7. Accuracy of different computational chemistry methods – selection of appropriate computational chemistry method based on the obtained energy difference.  Seminar 8. Accuracy of different computational chemistry methods - election of appropriate computational chemistry method based on description of the electronic properties of molecules and calculation speed.  **Topic 4**  **The use of computational chemistry for solution of chemistry related problems. L4 S10 Lw16**  Lecture 10. Use and limitations of *ab initio* and density functional theory methods for calculation of characteristic properties of molecules and chemical reactions. Solvation and approaches for its modelling.  Lecture 11. Additional aspects of computational chemistry. Trends in development of computational chemistry methods.  Seminar 9. Possibilities to analyze reaction thermodynamics and kinetics using computational chemistry.  Seminar 10. Description of electronic properties of molecules: molecular orbitals, electrostatic potential maps.  Laboratory work 1 and 2. Electrostatic potential maps and their use in comparison of properties of molecules. Chemical reactions and modelling their energy and rate.  Laboratory work 3. Determination of equilibrium constant from measurement of NMR spectra and computational calculations.  Laboratory work 4. Use of experimental and calculated infrared spectra for identification of intermolecular interactions.  Seminar 11. Analysis of a scientific article of computational chemistry, presentation. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Civil protection*** |
|  | *Chemistry* |
| ***Credits*** | 1 |
| ***Total Number of Contact Hours*** | 16 |
| ***Number of Lecture Hours*** | 12 |
| ***Number of Seminar and Practical Assignment Hours*** | 4 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 24 |
| ***Course Approval Date*** | 13.08.2020 |
| ***Course Developer*** | Dr.chem*.* Ilva Nakurte |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The purpose of the course is to provide and promote students’ understanding, refine a knowledge, facilitate skills and attitude on civil protection issues, by looking on the role of civil protection system in Latvia (also its framework in the EU and NATO), the organization and management structure, and main tasks of the system’s subjects.  Tasks of the course are to:   1. To explore the disaster management principles and planning aspects; 2. analyse the legal and practical measures of cooperation among state, local government and other stakeholders during disaster situations, opportunities of involvement of resources; 3. To give an insight on possible daily dangerous situations and threats, considers and provides safe behavior principles and actions during such situations; 4. To describe the role, aim and task of early warning and notification system; 5. To ensure that students are familiar and aware about the role of media (social networks) and its impact on information dissemination during the emergency situations and disasters; 6. To ensure that students obtain general knowledge on disaster medical system and the role of first aid.   The languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. Understands specific civil protection issues in Latvia and the European Union and on first aid; 2. Understands the structure, legal framework, organisation and management of the civil protection system; 3. Explains tasks, rights and obligations of state, municipalities, legal and natural persons in the field of civil protection; 4. Describes objects of increased danger, the duties and rights of the owner or legal holder thereof; 5. Understands civil protection commission of local governments, planning of measures, risk assessment, hazardous substances, their classification and requirements for their storage and transport; 6. Understands the prayer and delivery of international assistance; 7. Describes personal protective equipment in the event of a disaster (e.g. filter gas masks, anti-chemical protective clothing); 8. Understands the specific legal regimes (emergency and exceptional situation);   Skills:   1. Applicates the acquired knowledge on the role and responsibilities of the state, municipalities and other organizations in the planning of possible catastrophes and measures, implements various measures in case of danger; 2. Provides first aid in life-critical situations (e.g. stopping dangerous bleeding, resuscitation measures), as well as calls for assistance;   Competence:   1. addresses problems and applicates knowledge of the organisation and behaviour of the civil protection system in potential hazardous situations (including basic first aid knowledge) and the prevention of potential risks by establishing principles of safe behaviour, depending on the nature. | |
| ***Course Plan*** | |
| 1. Civil protection system in Latvia. L1 2. Disaster management, planning and implementation measures. L2 3. Potential disasters and their consequences. L1 S1 4. Context of civil protection in european union and nato, procedures of receiving and requesting humanitarian assistance. L1 5. Early warning and notification system. L1 6. Organization of disaster medicine system and provision of medical first aid. L1 S2 7. Planning of civil protection in local governments, merchants and institutions. L1 8. Requirement of classification, storage and shipping of dangerous chemical goods and their mixtures. L1 9. Procedures and behavior in case of fire and evacuation procedures. L1 10. Experience and lessons learnt from international missions. L1 11. The role of the media in emergencies and disasters. L1 S1   L - lecture, S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is organized on individual basis and / or small working groups by assigning the following tasks: to prepare independently for seminars and intermediate examinations; to study literature on topics related to respective course. | |
| ***Requirements for Awarding Credits*** | |
| Attendance of lectures and seminars at least 90%.  Intermediate tests:   1. Test of workshops on first aid - 25% 2. Test of seminars on the organisation of the civil protection (CP) system - 25%   Final examination:   1. Exam (written):    * Part 1 First aid - 25%    * Part 2 Civil Protection (CP) system, tasks and action - 25% | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | | 1. Test of workshops on first aid. | X |  |  |  |  |  |  |  |  | X |  | | 1. Test of seminars: Civil protection (CP) system. | X |  | X | X |  |  | X |  |  | X |  | | 1. Exam: Part 1- First aid. |  |  |  |  |  |  |  |  |  | X | X | | 1. Exam: Part 2 - Civil Protection (CP) system, tasks and action. | X | X | X | X | X | X | X | X | X |  | X | | |
| ***Compulsory Reading List*** | |
| 1. Kusiņš, J., Kļava, G. “Civilā aizsardzība”, Rīga, “Drukātava”, 2011., 377 lpp.; 2. Pirmās palīdzības sniegšanas pamatzināšanu apmācības programmas vadlīnijas. Pieejams: http://www.nmpd.gov.lv;Basic 3. Drošības padomi; Tiešsaite: http://vugd.gov.lv 4. Komisijas dienestu 2010.gada 12.decembra darba dokuments SEC(2010) 1626 galīgā redakcija “Riska novērtēšanas un kartēšanas vadlīnijas katastrofu pārvaldībai”, Brisele, 2010., 43.lpp. Pieejams: http://ec.europa.eu/echo/index\_en; 5. Gowing, N., “Skyful of Lies and Black Swans: the new tyranny of shifting information power in crises”. Univeristy of Oxford, 2009., 94.lpp. 6. Wendling, C., Radisch, J., Jacobzone,S. The Use of Social Media in Risk and Crisis Communication OECD Working Papers on Public Governance, No. 24, OECD Publishing. 2013 Pieejams: http://dx.doi.org/10.1787/5k3v01fskp9s-en. | |
| ***Further Reading List*** | |
| 1. Civilās aizsardzības un katastrofas pārvaldīšanas likums; 2. Nacionālās drošības likums; 3. Ugunsdrošības un ugunsdzēsības likums; 4. Likums par ārkārtējo situācijas un izņēmuma stāvokli; 5. Valsts civilās aizsardzības plāns; 6. Valsts katastrofu medicīna plāns; 7. Eiropas Parlamenta un Padomes 2013.gada 17.decembra lēmums Nr.1313/2013/ES “Par Savienības civilās aizsardzības mehānismu”. 8. Latvijas Republikas Ministru kabineta noteikumi: https://likumi.lv/ MK noteikumi. | |
| ***Periodicals and other sources*** | |
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| ***Course Content*** |  |
| Theme 1. CIVIL PROTECTION SYSTEM IN LATVIA  Civil protection system in Latvia and its role in the national security system; Legal framework for provision of civil protection system; Organization and management, structure and main tasks of civil protection; Planning of civil protection measures; Liability regarding non-observance of civil protection requirements; Tasks and rights of local governments, merchants and institutions in civil protection; Rights and duties of inhabitants in civil protection; Examples from practice.  Theme 2. DISASTER MANAGEMENT, PLANNING AND IMPLEMENTATION MEASURES  Measures of disaster management planning – prevention, preparedness, response and mittigation; Risk assessment; State civil protection plan; Tuition and exercises in civil protection; Graduation levels of disasters; Engagement of resources in disaster management; Involvement of legal and natural persons in response measures; State material reserves; Special legal regimes – Emergency situation and State of exception; Civil-military cooperation.  Theme 3. POTENTIAL DISASTERS AND THEIR CONSEQUENCES  Potential disaster (in Latvia and outside) and their consequences – natural disasters, man-made disasters, technogenic disasters, public disorders, terrorist attacks, armed conflicts, epidemics, epizootics and epiphytoties; Establishments of subject to increased risk, criteria for their specification and measures for risk reduction; Evacuation planning measures; Radiation safety, individual and collective protection measures; Examples of practice. Workshop/seminar.  Theme 4. CONTEXT OF CIVIL PROTECTION IN EUROPEAN UNION AND NATO, PROCEDURES OF RECEIVING AND REQUESTING HUMANITARIAN ASSISTANCE  Bilateral framework of cooperation in civil protection; Cooperation in Baltic Sea Region; European Union civil protection mechanism; The role of civil protection in NATO; Reception of and request for humanitarian assistance. Examples of practice.  Theme 5. EARLY WARNING AND NOTIFICATION SYSTEM  Early warning and notification system, aim, tasks and provisions of operation; Behaviour of population; Readiness examination for sirens; New technologies in early warning and notification; Examples of practice.  Theme 6. ORGANIZATION OF DISASTER MEDICINE SYSTEM AND PROVISION OF MEDICAL FIRST AID  Organization of disaster medicine system, management, planning, coordination and activation; Emergency medical situations and emergency public health situations; resources of disaster medicine system; Emergency medical response plans; Examples of practice; First aid and emergency medical treatment; CPR/CAB scheme and practical demonstration and training; Shock treatment; Severe bleeding; Drowning treatment; Wound care; Trauma and other injuries. Seminar.  Theme 7. PLANNING OF CIVIL PROTECTION IN LOCAL GOVERNMENTS, MERCHANTS AND INSTITUTIONS  Civil protection plan of local government, merchant and institution; Defined aim and tasks, development and implementation of civil protection plans; Civil protection commission of local municipality, tasks, rights, structure and management; Examples of practice.  Theme 8. REQUIREMENT OF CLASSIFICATION, STORAGE AND SHIPPING OF DANGEROUS CHEMICAL GOODS AND THEIR MIXTURES  International and domestic transportation and shipping of dangerous chemical goods by road transportation, railway, air transportation and sea; European regulation on classification, labelling and packaging of dangerous substances and mixtures – CLP; European regulation on registration, evaluation, authorisation and restriction of chemicals – REACH; Material safety data sheets; Storage, labelling, monitoring and control of dangerous chemical substances and mixtures; Permits of A and B categories for polluting activities; Examples of practice.  Theme 9. PROCEDURES AND BEHAVIOUR IN CASE OF FIRE AND EVACUATION PROCEDURES  Behaviour in case of fire; Smoke detectors; Fire extinguishers; Evacuation procedures (home or public facilities, during disasters); Disaster survival kit (bag); Examples of practice.  Theme 10. EXPERIENCE AND LESSONS LEARNT FROM INTERNATIONAL MISSIONS  Practical experience from international missions, opportunities and challenges, lessons learnt, required competence, mission mandate; Possible participation in international missions – disaster assistance, diplomatic missions, peacekeeping mission, war operations, humanitarian aid crises, volunteer work under UN system or other organization); Examples of practice.  Theme 11. THE ROLE OF THE MEDIA IN EMERGENCIES AND DISASTERS  The role and impact of mass media and social media on information during the crisis situations and disasters; Accessibility, distribution, broadcasting and manipulation of information; The impact of information on decision making, opportunities and challenges; Workshop, seminar; Examples of practice. | |

**LATVIJAS UNIVERSITĀTES**

**STUDIJU KURSA APRAKSTA FORMA**

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| ***Study Course Title*** | ***Environment protection*** |
|  | Environmental science |
| ***Credits*** | 1 |
| ***Total Number of Contact Hours*** | 16 |
| ***Number of Lecture Hours*** | 14 |
| ***Number of Seminar and Practical Assignment Hours*** | 2 |
| ***Number of Laboratory Work Hours*** | 0 |
| ***Independent Study Hours*** | 24 |
| ***Course Approval Date*** | 15.01.2021 |
| ***Course Developer*** | *Dr.chem.,* Jānis Zaļoksnis |
| ***Prerequisite Knowledge*** | Prerequisite knowledge required for the acquisition of the course corresponds to the study programme admission requirements and the general knowledge, skills and competences obtained at the previous level of education. |
| ***Study Course Abstract*** |  |
| The aim of the course is to provide basic knowledge of environmental science, its interdisciplinary nature and applications. In course are described potential impacts of human activities and their influence to environment, as well as importance not only about direct impacts, but also indirect effects and possible cumulative effects to nature. Environmental science and their functions are described using systemic approach about element and energy fluxes, as well as explaining different protection strategies of nature and ecosystems. Environmental degradation and effects of climate change caused by the society with unsustainable usage of resources and management methods will be analyzed, also will be shown sustainable development goals and existing experience, applications. The course provides general knowledge of environmental processes, the impact of human activities on them and potential solutions to existing environmental problems and preventive actions.  The tasks of the course is:   1. to provide environmental education in the study programs of higher education institutions, taking into account the provisions of the Environmental Protection Law (29.11.2006) article 42; 2. to provide theoretical knowledge of environmental science and sustainable development necessary to participate in smart decision-making processes and predict actions to ensure economic development, sustainable principles of resource management and mining without negative impact on the environment and its quality.   Languages of instruction are Latvian and English. | |
| ***Learning Outcomes*** |  |
| Knowledge:   1. explains the basic principles of environmental science and the issues we are faced nowadays; 2. understands main environmental problems and their possible solutions; 3. is aware of potential risks of human interaction with environment; 4. understands the principles of nature protection and sustainability in solving related problems;   Skills:   1. independently develops and improves knowledge of environmental issues (main environmental problems and their possible solutions); 2. acts in the context of the circular economy and is critical of published environmental information in media; 3. analyses environmental, natural, and related economic and social problems, environmental quality in Latvia and Europe;   Competence:   1. identifies nature conservation issues and addresses them to the appropriate level of competence; 2. implements activities in accordance with the basic principles of sustainable development; 3. applicates knowledge about significant environmental issues in practice. | |
| ***Course Plan*** | |
| 1. Introduction to Environmental Science. L2 2. Nature protection. L2 3. Resources. L2 4. Environmental pollution. L2 5. Climate and adaptation to climate change. L2 6. Sustainable development. L2 7. Seminar on environmental problems and their causes. S2 8. Environmental health. L2   L – lecture S - seminar | |
| ***Characterization of students' independent work organization and tasks*** | |
| Students' independent work is organized individually, but in practical work - in small groups.  Independent tasks:   1. To study literature related to the study course topics 2. Watch films about environmental issues including "Home”, “An Inconvenient Truth," "Age of Stupid"; 3. During the course, watch the LTV - 1 program "Environmental Facts" and prepare a final evaluation; 4. Prepare for seminars; 5. To make a subjective assessment of the state of the environment in Latvia; 6. Prepare recommendations to the responsible Latvian institutions on improvement of the state of the environment; 7. Prepare recommendations for improvement of environmental protection course; 8. Develop and submit a concluding essay, such as My Future Environmental Actions. | |
| ***Requirements for Awarding Credits*** | |
| Attendance of lectures and seminars at least 80%.  Intermediate tests:   1. Seminar or essay - 25% 2. Individual assignment or test - 25%   Final examination:   1. Environmental protection - 50%   Independent assignment or essay is implemented depending on the supplementation of the competences required for the study program, in relation to environmental protection, and following the chosen and agreed topic with the lecturer. | |
| ***Criteria for Evaluation Learning Outcomes*** |  |
| In accordance with Regulations No. 141, No. 512, No. 240 of the Cabinet of Ministers of the Republic of Latvia and the Decision of the Senate of the University of Latvia as of 29.06.2015. No. 211, at the end of the course, students' knowledge is evaluated on a 10-point scale according to the following criteria: the amount and the quality of the obtained knowledge, acquired skills and competence in compliance with the planned learning outcomes.  ***Evaluation of Learning outcomes***   |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | Type of assessment | Learning outcomes | | | | | | | | | | | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | | 1. Seminar or essay | X | X |  |  | X | X |  |  | X | X | | 1. Individual assignment or test |  |  | X | X |  |  | X |  |  | X | | 1. Exam | X | X | X | X | X | X | X | X | X | X | | |
| ***Compulsory Reading List*** | |
| 1. Botkin, D. B., Keller, E. A. Environmental Science: Earth as living planet. 5th ed. J.Wiley: NY, 2004 2. Kļaviņš M., Vides piesārņojums un tā iedarbība. LU Akadēmiskais apgāds. Rīga, 2012. 3. Kļaviņš, M. (ed.)Vides zinātne. LU Akadēmiskais apgāds. Rīga, 2008. 4. Kļaviņš, M., Zaļoksnis, J. (ed.) Vide un ilgtspējīga attīstība. LU Akadēmiskais apgāds. Rīga, 2010. 5. Nikodemus O., Brūmelis G. Dabas aizsardzība. LU Akadēmiskais apgāds. Rīga, 2015 6. Ryden, L., Migula, P., Andersson, M.(ed.). Environmental Science.Baltic University Press: Uppsala, 2003. | |
| ***Further Reading List*** | |
| 1. Blumberga, A., Blumberga, D., Kļaviņš, M., Rošā, M., Valtere, S. Vides tehnoloģijas. LU Akadēmiskais apgāds, Rīga, 2010. 2. Kļaviņš, M, Cimdiņš, P. Ūdeņu kvalitāte un tās aizsardzība, LU: Rīga, 2003. 3. Kļaviņš, M., Zaļoksnis, J. Ekotoksikoloģija, Elpa: Rīga, 2005. 4. Meadows, D.H., Meadows, D.L., Randers, J. Beyond the limits. Chelsea Green Publishing Co., Post Mills, USA, 1992. 5. Römpczyk, E. Gribam ilgtspējīgu attīstību. Friedrich-Ebert-Stiftung, Rīga, 2007. 6. Starlings, G. Valsts sektora pārvalde. Valsts administrācijas skola. USIS RIGA, 1999. 7. Zaļoksnis, J. (ed.) Baltijas reģiona ilgtspēja. 1.-10. sējumos. LU, Rīga, 2001. 8. Zaļoksnis, J. (tulk.) Pārsniedzot robežas. LU, Rīga, 1995. 9. Zaļoksnis, J., Kļaviņš, M., Brikše, I., Meijere, S. Vides vadība. LU Akadēmiskais apgāds, Rīga, 2011. | |
| ***Periodicals and other sources*** | |
| 1. European Environment Agency (EEA) https://europa.eu/european-union/about-eu/agencies/eea\_en 2. European Union Network for the Implementation and Enforcement of Environmental Law: https://www.impel.eu/topics/nature-protection/ 3. LU Ģeogrāfijas un Zemes zinātņu fakultāte http://www.geo.lu.lv/vides\_izglitiba 4. NVO Zaļā Brīvība mājas lapa http://www.zalabriviba.lv/ 5. United States Environmental Protection Agency https://www.epa.gov/ 6. “Vides fakti” Raidījumu cikls 7. Vides ministrijas mājas lapa http://www.varam.gov.lv/ 8. Zinātniskie žurnāli ar pārstāvētu pētījumu tematiku, kas saistīta ar Vides zinātni: Waste Management; Science of Total Environment; Journal of Cleaner Production; | |
| ***Course Content*** |  |
| Theme 1  **Environmental science and environmental protection**  History of the environmental science. Humans and environmental interaction. Environmental science principles and major divisions. Environmental science integrative and interdisciplinary role on nature. Systems approach.  Theme 2  **Nature conservation**  Nature conservation history. The loss of biodiversity in the world and Latvia: causes and consequences. Biodiversity in the world and Latvia. Biodiversity conservation techniques. Special protected areas. Habitats and species, habitat recovery. Trade of different species - its limitation. Problems with the alien species. Nature conservation plans and actions. The main requirements of the EU nature conservation policy. International co-operation on nature conservation. Citizens and public organizations role in environmental and nature protection.  Theme 3  **Natural** **resources**  Environmental and natural resources, their classification. Use of natural resources, depletion and exhaustion. Resources of the mineral substances. Soil, forest and water resources. Non-renewable energy resources: coal, peat, oil, natural gas, uranium ore. Renewable energy: solar energy, geothermal energy, water energy, wind energy, ocean wave and tidal energy, biomass. Land-use options for ensuring humanity.  Theme 4  **Environmental pollution**  Atmospheric pollution, its sources and exposure. Air pollutants. Indoor air pollution. Air quality assessment and air monitoring. Air quality standards. Air pollution reduction needs in Latvia. Earth's ozone layer and its protection. Water pollution. Soil pollution and degradation. Contaminants of the national economy and in everyday life. Environmental health concept. Pollutant’s impact on people and ecosystems. Toxic effects. Physical (noise, radiation) and biological (microorganisms) factors. Environmental pollution and exposure influences rationing.  Theme 5  **Climate change**  Earth's climate and its variability. Energy turnover role in the Earth's energy balance. Human-induced climate changes. Greenhouse effect gases. Manifestations of climate change, the risks and possible consequences. International laws to mitigate climate change. The climate policy. Climate technologies. CO2 capture and storage technologies. The transition to a low carbon society. Adaptation to climate changes.  Theme 6  **Sustainable development**  Sustainable development as an essential part of postmodern culture. Global changes and social timeserving in the world. Sustainable development as an intergenerational issue. Growth and limits to growth. The role of science and scientists for sustainable development problem identification and solving. Concept of sustainable development. Sustainable development  Theme 7  **Seminar**  Seminar about important environmental issues and their causes. Factors that effect different reactions (positive and negative) in environment and examples of them. What type of behaviour could improve or negatively affect environment in future.  Theme 8  **Environmental health**  Environmental health conception. How to assess the hazardousness of substances? Effects of pollutants and physical factors on humans and ecosystems. Types of toxic effects. Effects of environmental pollutants and factors on human beings. Effects of environmental pollutants on endocrine system. Genotoxic effects of environmental pollutants and factors. Carciogenic effects of environmental pollutants and factors. Teratogenic substances. Exposure factors impact on people and ecosystems. Radioactive radiation , radioactive elements and their properties. The noise impact on people. Environmental pollution and exposure factors on rationing. | |
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