Course title	**Quantum physics**
Course code	**Fizi1064 (eks)** **Fizi1063(iesk)** **Fizi1058-DP***
Scientific field	Physics
Scientific subfield	General physics
Credit points	4
ECTS credits	6
Total contact hours (CH) *Number of hours for lectures* *Number of hours for seminars and practical assignments* *Number of hours for laboratory assignments* *Number of hours for course paper*	64 32 16 *16*

Course developer (-s)
Dr. phys, docents Amandis Podiņš, Dr. paed. Doc. L. Jonāne

Prerequisite knowledge (course title, part of the program where the course is learnt)
Highschool physics course

Course abstract:

Study course "Quantum physics" is intended for students of bachelor study program "Physics". The course deals with atoms, molecules and fundamental questions in particle physics, focusing on micro-research methods, basic experiments, concepts and theoretical models. Basics of quantum mechanics, quantum effects in solids are explained. The course also includes laboratory assignments in atomic physics and problem solving for understanding theoretical questions.

Learning outcomes:

Students will:

- gain knowledge and understanding of the atomic structure, atomic models, micro research methods and fundamental laws, their applicability borders
- apply knowledge in problem-solving, demonstrate it in presentations and seminars,
- demonstrate the ability to plan and conduct research, analyze and explain problems of physical content,
- develop and strengthen the skills needed for further studies - physical experimenting and measuring
- analyze, summarize and evaluate the theoretical knowledge and experimental skills and be able to apply them in physical content studies

Course content:

1. Energy quantization. Atomic structure, models and research methods.
2. Particles and waves. Basics of quantum mechanics.
3. Atomic spectra, periodic system's analysis from quantum physics' point of view.
4. Molecular structure and spectra.

Course plan:

Course structure: Lectures - 32 CH., Practical assignments -16 CH. Laboratory assignments – 16 CH.

Topics of lectures:

1. The atomic and nuclear physics development history. Rutherford experiment of alfa-particle dissipation. Nuclear atomic model. Rutherford formula for alfa-particle dispersion from nuclei.
2. Empirical correlations in hydrogen atom and hydrogen ion spectra. Solar spectrum - first experimental studies, Fraunhofer lines. Balmer's formula. Rytberg's formula and Rytberg's constant. Hydrogen spectrum line series. Hydrogen ion spectra, Pickering's series. Bohr's

hydrogen model. Bohr's postulates and their conflict with the classical physics concepts. The angular momentum quantization in hydrogen atom according to Bohr's theory. Bohr's radii of electron orbits. Energy levels of hydrogen atom. Role of nucleus movement in precise determination of Rytberg's constant. Isotopic shift of spectral lines, heavy hydrogen detection.

3. Franck – Hertz's experiments. Franck-Hertz experimental device. Bohr's theory comparison with experiment. Difficulties of Bohr's theory. Experimental results and their interpretation. Fluorescence registration in the modified Franck-Hertz experimental device, interpretation of results.
4. Particles and waves. De Broglio hypothesis of particle-wave properties. Geometrical optics limitations. The hypothesis of limitations of corpuscular description of matter. De Broglio's waves. Bohr's atom model interpretation based on de Broglio's hypothesis.
5. Electron diffraction. Davisson - Germer's experiments on electron diffraction. Experimental equipment scheme, the results obtained. Angular distribution of scattered electrons depending on their speed. Electron scattering monocrystalline dependence on crystallographic plane orientation.
6. Photo effect. Einstein's formula for photo effect, its conclusions that are contrary to classical physics. Einstein's quantum interpretation. Experimental verification of Einstein's formula. Milliken's experiments.
7. Compton's scattering. X-ray scattering in a substance. Compton's scattering physical model and its theoretical description. Compton's wavelength of an electron. Compton experimental equipment diagram and the registered signals. Particle - wave dualism expression in Compton's experiments. X-ray diffraction.
8. Physical meaning of de Broglio waves. De Broglio's wave phase and group velocity. Wave packets velocity dispersion. De Broglio's wave module square interpretation as the probability density of the particles found in a particular point in space.
9. Heisenberg uncertainty relations, the physical meaning of uncertainty relations, their solution for rectangular wave package. Uncertainty in the interaction of the measurement procedure. Bohr's complementarity principle. Atom minimum size's and minimum energy's connection with Heisenberg's uncertainty relation.
10. Basics of quantum mechanics. Schrödinger equation. Wave function and its physical meaning. Particle in infinitely deep potential well. Energy and wave function of particle. Probability density of spatial location of particle and its comparison with the probability density in classical physics. Particle in finit potential well. Harmonic oscillator. Approximating evaluation of harmonic oscillator energy levels. Harmonic oscillator wave functions of quantum and classical particles the probability of finding harmonious oscillator. Overcoming potential barrier. Quantum Tunnelling. Tunneling probability dependence on the potential barrier width. Cold electron emission and α- decay as quantum tunnelling examples.
11. Energetic states and the wave functions of hydrogen atoms. Hydrogen energetic levels, wave function's angular and radial part. Quantum numbers in hydrogen atom, their physical meaning. Angular momentum vector model in hydrogen atom. Multi-electron atomic structure. Helium atom spectrum.
12. Electron spin. Stern-Gerlach and Einstein-de Haas experiments. Electron momentum - spin, its interpretation. Magnetic dipole moment, associated with spin of electron. Stern-Gerlach experiment, equipmental scheme and results. Einstein - de Haas experimental scheme and the results obtained.
13. Pauli' s exclusion principle. Filling of electron shells in atoms. Wave function symmetry. Pauli principle phenomenological formulation and explanation, based on particle identity principle. Order of electron shell filling and periodic system analysis. Period length analysis. Lanthanides and actinides.
14. X-ray spectrum. Regularities in X-ray line spectrum. Moseley's law. X-ray spectrum explanation in the independent electron model. Structure of X-ray spectral line.
15. Atoms in external fields. Atoms in a magnetic field. Zeeman effect. Classic atomic radiation polarization in a magnetic field. The simplest description of the Zeeman effect in the context of quantum physics. Electron paramagnetic resonance. Anomalous Zeeman effect. Finding Lande factor in atoms with spin different from zero. Spectral line splitting and polarization in magnetic field in the case of anomalous Zeeman effect. Paschen-Back effect. Empirically observable changes in the hydrogen spectrum in a strong magnetic field. Atomic spectrum in case of Paschen-Back effect.
16. Molecular spectra. General characteristics of spectra. Physical essence of ionic bond formation mechanism. Intermolecular force acting in ion bond case. Ion bond energy and its length.

Covalent bond. Shape of "electron cloud", the formation of a covalent bond. Singlet and triplet states, antibonding and bonding orbitals. Spontaneous and induced radiation. Quantum generators and their applications.

In seminars topics of lectures are studied in-depth, theoretical problems are solved.
Laboratory assignments**:**

1. Spectroscopy
2. Determining charge-to-mass ratio (e/m) of the electron.
3. Photoelectric effect.
4. Franck-Hertz's experiment.
5. Milliken's experiment.

Individual work: study of theoretical questions, solving home exercises and tests.

Requirements for awarding credit points:

At the end of the course there is a test and an oral exam.
To pass the test, following requirements have to be met:
1) Seminar attendance and practical assignments - 20%
2) preparation and presentation of three chosen topics - 30%
3) performing housework (24 tasks) - 50%
. The student gives an overview of two questions from the course.
Study methods and forms - lectures, practical assignments, laboratory assignment and defense, consultations, individual work (problem solving, preparation of presentation).

Compulsory reading:

1. Eiduss I., Zirnītis U. Atomfizika. - R.: Zvaigzne, 1978.
2. Rolovs B. Kodolfizika. - Rīga, 1964.
3. Pakers V. Atoma un kodolfizika. 1., 2., 3., 4., 5., 6. daļa. - Daugavpils: DPU, 1994.
4. Sprieslis I., Teiva U. Augstskolu reflektantiem. - R.: Zvaigzne, 1993.
5. Valters A. Fizika. - R.: Zvaigzne, 1992.
6. Krūmiņš J. u.c. Uzdevumu krājums vispārīgajā fizikā. - R.: Zvaigzne, 1971
7. Apinis A. Fizika. - R.: Zvaigzne, 1972. - 706 lpp.
8. Grabovskis R. Fizika. - R.: Zvaigzne, 1983. - 644 lpp.
9. Volkenšteine V. Uzdevumu krājums fizikā. - R.: Zvaigzne, 1968.
10. Laboratorijas darbu aprakstu krājums optikā un kodolfizikā. 1. un 2. daļa.
11. Jansons L., Zambrāns A., Badūns A., Ginters M., Jansone A. Fizikas praktikums. - R.: Zvaigzne, 1979. - 504 lpp.
12. Krūmiņš J., Lemberga B., Platacis J., Students O. Uzdevumu krājums vispārīgajā fizikā. - R.: Zvaigzne, 1971. - 420 lpp.
13. Volkenšteine V. Uzdevumu krājums fizikā. - R.: Zvaigzne, 1968. - 353 lpp.
14. Krūmiņš J., Ertele B., Zambrāns A. Fizikas uzdevumu risināšanas metodika. - R.: Zvaigzne, 1980. - 412 lpp

Further reading:

1. Bransden & C. J. Joachain. Physics of Atoms and Molecules, 2nd edition
2. H. C. Ohanian. Physics, Vol 2. New York: W.W. Norton & Company, 1985, 1012 pp.
3. J.D. Cutnell, K.W. Johnson. Physics. (5-th) – New York: John Wiley & Sons, 2001., 1002 pp.
4. D. Halliday, R. Resnich, J. Walker. Fundamentals of Physics (Extended) – New York: John Willey & Sons, Inc., 1997., 1142 pp.
5. A.L. Standford, J.M. Tanner. Physics for Students of Science and Engineering. - Orlando, Florida: Academic Press, Inc., 1985, 804 pp.
6. E. Jones, R. Childers. Contemporary College Physics. – USA: McGraw-Hill,1999, 1025 pp.
7. A.Hobson. Physics. Concepts and connections. – New Jersey: Prentice-Hall, 1999., 536 pp.
8. M. Merken. Physical science with modern application. 5-th edition. – Saunders College Publish, 1993, 680 pp.

9. R.A. Serway, R.J. Beichner. Physics for Scientists and Engineers. Vol. 1. – Saunders College Publishing: 2000., 705 pp..
10. R.A. Serway.Physics For Scientists & Engineers with Modern Physics, 3-rd edition - Orlando, Florida: 1992, 1444 pp.
11. E. Hecht. Physic Calculus.- California; Brooks/Cole Company, 1996, 1240 pp.
12. R.Wolfson., J.M.Pasachoff. Physics. – Printed in USA: Little, Brown & Company, 1987
13. R.T. Weidner, M.E. Brown. Physics. – Massachusetts: Simon @ Schuster,1989, 945 pp.
14. Hans. C.Ohanian. Principles of Physics. W.W.Norton & Company, Inc., 1994
15. Eugene Hech. Physics: calculus, Brooks/Cole Publishing Company, 1998
16. David Halliday, Robert Resnick, Jearl Walker . Fundamentals of Physics, enhanced problems version, sixth edition,2003, John Wiley& Sons
17. John D.Cutnell & Kenneth W. Johnson. Physics. 5th edition, John Willey & Sons, 2001.
18. P.A.Tipler. Physics for Scientists and Enginiers, Third Edition, Extended version, 1991

Periodics and other sources of information

1. Nature. Physics.” Nature publishing group.
2. http://phys.org/physics-news/quantum-physics

Notes:

Study programs and their sections (A, B, C, D) which this course belongs to:

BSP Physics, section A