COURSE UNIT DESCRIPTION

Course unit title	Code
Quantum Mechanics	

Annotation
Electricity and magnetism is third course on classical physics. The course is dedicated for understand electrical and magnetic phenomena. Electric and magnetic forces and fields are introduced. The electromagnetic laws are described using calculus, and are summarized by Maxwell equations in the end of the course. The strong focus during the course is on performing laboratory works and problems solving.

Lecturer(s)	Department, Faculty
Coordinating: doc. dr. Tadas Malinauskas	Faculty of Physics

Study cycle	Type of the course unit
Bachelor	Mandatory

Mode of delivery	Semester or period when it is delivered	Language of instruction
Auditory and remote teaching	Autumn semester	English

Requisites	
Prerequisites: The course presumes a mathematics background that includes basic algebra and trigonometry, functions, vectors, matrices, complex numbers, ordinary differential and integral calculus, and ordinary and partial differential equations. The course includes an optional and ungraded refresher background mathematics sections. In physics, students should understand elementary classical mechanics and basic ideas in electricity and magnetism. (The course explicitly does not require knowledge of more advanced concepts in classical mechanics, such as Hamiltonian or Lagrangian approaches, or in electromagnetism, such as Maxwell's equations.)	**Co-requisites (if relevant):** None

Number of ECTS credits allocated	Student's workload (total)	Contact hours	Individual work
5	140	64	76

Purpose of the course unit: programme competences to be developed		
The primary objective of this course is to provide introduction in quantum mechanics to individuals who possess a solid understanding of physics or engineering at the university level. Quantum mechanics concepts and techniques are indispensable in numerous fields of engineering, technology and science, including materials science, nanotechnology, electronic devices, and photonics. This course offers a comprehensive introduction to quantum mechanics and its practical applications.		
Learning outcomes of the course unit	**Teaching and learning methods**	**Assessment methods**
Demonstrate proficiency in explaining fundamental concepts employed in quantum mechanics, including wave functions and operators.	Lectures, homework, problem solving	Homework, midterm and finals exams

They will be able to apply quantum mechanics concepts to describe basic quantum systems and calculate various measurable quantities	Lectures, homework, problem solving	Homework, midterm and finals exams
Ability to apply analytical and numerical methods to solve problems of quantum mechanics	Lectures, homework, problem solving	Homework, midterm and finals exams
Ability to address physical problems critically, identifying the laws and concepts that apply in a specific situation,	Lectures, homework, problem solving.	Homework, midterm and finals exams

Course content: breakdown of the topics	**Contact hours**							**Individual work: time and assignments**	
	Lectures	Tutorials	Seminars	Workshops	Laboratory work	Internship/work placement	**Contact hours, total**	**Individual work**	**Assignments**
1. **Introduction.** Introduction to Superposition. The wave-particle duality of matter and light.	2			2			**4**	**5**	Liboff 2 Chapter
2. **Experimental observations of Quantum Phenomena.** Atomic spectra. Photoelectric effect. Electron diffraction. Black body radiation.	2			2			**4**	**5**	Liboff 2 Chapter.
3. **Wave function.** Temporal and spatial frequency. Meaning of wavefunction. Normalization. Plane wave. Superpositon. Fourier analysis. Uncertainty Principle	2			2			**4**	**5**	Griffiths 1.
4. **Expectation value**. Uncertainty. Momentum operator. Operators. Eigenfunction, eigenavalue. Energy operator. Expresion of WF in different bases. Collapse of WF.	2			2			**4**	**5**	Griffiths 1.
5. **The Schrodinger Equation.** Expansion coefficients. Time evolution in QM. The free particle. The infinite square quantum well.	4			4			**8**	**8**	Griffiths 1.
6. **The finite square well**. Bound states vs scattering states. Symmetric and antisymetricsolutions. Commutation of operators.	2			2			**4**	**5**	Griffiths 2.6 Liboff 8.1
7. **Tunelling.** Wavepacket. Scattering from barrier. Tunelling through barrier.	2			2			**4**	**5**	Liboff 7.6
8. **The harmonic oscillator.** Operator method. Ladder operators.	2			2			**4**	**5**	Griffiths 2.3 Liboff 7.2,7.3 Miller 2.10
9. **Pertubation theory**. Time-independent pertubation theory. Hermitian operators.	2			2			**4**	**5**	Griffiths 6.1 Miller 6.3 Liboff 13.1
10. **Approximation methods in QM**. Functions and operators as vectors and matrices. Finite matrix method.	2			2			**4**	**5**	Miller 4.1-4.5, 6.
11. **Angular Momentum in QM**. Orbital Angular Momentum. Visualization of spherical harmonics.	2			2			**4**	**5**	Griffiths 4 Liboff 9
12. **The Hydrogen Atom**. Central Potentials. Separation of Variables. Quantum numbers and their significance.	4			4			**8**	**8**	Griffiths 4 Liboff 10
13. **Spin Wavefunctions**. Elements of Matrix Mechanics.	2			2			**4**	**5**	Griffiths 4

14. **Time-dependent perturbation theory**. Fermi's golden rule. Emission and absoption of Radiation.	2			2			**4**	**5**	Halliday 30 ch. Liboff 13.5, 13.6
Total	32			32			**128**	**76**	

Assessment strategy	Weight %	Deadline	Assessment criteria
Midterm exam	20	After 6 Lectures are finished	With 15-20 questions comprising multiple-choice, short-answer, and problem-solving questions, students will need to demonstrate a comprehensive understanding of the basic framework of quantum mechanics. Maximum score – 20 points.
Midterm exam	20	After 12 lectures are finished.	The assessment in a midterm exam will involve a combination of 15-20 multiple-choice questions, short-answer questions, and problem-solving questions. Students are expected to demonstrate a solid understanding of the fundamental principles of quantum mechanics, including the solutions of the Schrödinger equation for several different potentials. Maximum score – 20 points.
Final exam	40	During exam session	The assessment in a midterm exam will involve a combination of 15-20 multiple-choice questions, short-answer questions, and problem-solving questions. Students are expected to demonstrate a solid understanding of the fundamental principles of quantum mechanics, including the solutions of the Schrödinger equation for several different potentials. Maximum score – 40 points.
Homeworks (problem solving).	20+	All semester	About 25 problems have to be solved at home during the semester. There is possibility to collect more than 20 points.
"The final score will be determined using the formula: Score = round(Points/10). If a student does not pass the course through accumulative scoring, they will be required to take an exam without accumulative scoring. This exam will include a combination of written and oral questions, providing students with the opportunity to demonstrate their knowledge and understanding of the course material.			

Author	Publishing year	Title	Issue of a periodical or volume of a publication; pages	Publishing house or internet site
Required reading				
David A. B. Miller	1991	Quantum Mechanics for Scientists and Engineers		Oxford
Recommended reading				
David J. Griffiths	2005	Introduction to Quantum Mechanics	Second Edition, Chapters 1-4,6,9	Pearson Education
R. L. Liboff	2003	Introductory Quantum Mechanics	Fourth edition	Addison-Wesley
J. Chmeliov, V. Butkus, L. Valkūnas	2018	Kvantinė fizika		Vilnius: Vilniaus universiteto leidykla