Handbook of modules for the study course Physics, M.Sc.

July 2025

valid for all students enrolled
from WS 2024/25 onwards

The most important details

Duration:	4 semesters full-time
Location:	Tashkent
Qualification:	Master of Physics, M.S.
Course start:	Annually in the Autumn term
Language:	Uzbek
Preparatory internship:	During the 1st–3rd semesters, students of the Master's program in DP Physics a scientific and pedagogical internship by teaching undergraduate students of the Faculty of Physics. The purpose of this internship is to gain practical experience in university-level teaching and to strengthen students' practical skills in teaching physics. In the 4th semester, they are required to complete a research internship.
Internship/ study abroad:	no
Master thesis:	During all 4 semesters, master's students of the Physics program work on their master's thesis under academic supervision. The thesis is prepared in accordance with the academic standards of the program and is defended at the end of the 4th semester.
Calculation of workload:	1 CP equals 30 hours per semester
Examinations:	The assessment of students' knowledge is carried out in accordance with the Order of the Minister of Higher and Secondary Specialized Education of the Republic of Uzbekistan "On the Approval of the Regulation on the System of Monitoring and Assessing Students' Knowledge in Higher Educational Institutions"[1], developed under the credit–modular system.
Literature:	Literature mentioned in the module descriptions are first recommendations and do not replace the syllabus of the module. The module coordinators assume as a rule that the titles specified always refer to the most current version.
Attendance:	Attendance of all seminars, exercises and lab courses is mandatory.

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[1] https://lex.uz/uz/docs/3916793

Content

Module No./ Modul-Nr.	Subjects / Module	Module Requirements/ Modulvoraus-setzungen	CH/ SWS	Type					Ex/Prü		CP*	CH / SWS			
				L/V	S	E/Ü	LC /Pr	Pro	Graded/ Benotet	Attestation/ Testat		WT / WS 1	ST / SS 2	WT / WS 3	ST / SS 4
1.00	**Mandatory subjects**		**24**	**12**	**4**	**4**	**4**				**36**	**24**	**12**		
ILTM1106	Methodology of Scientific Research		4	2		2			P		6	6			
MFOM1106	Methods of Teaching Specialized Disciplines		4	2	2				P		6	6			
FZTU1106	Modern Research Methods in Physics		4	2			2		P		6	6			
NTTN1106	Theory of Nonlinear Oscillations and Waves		4	2		2			P		6	6			
ENMT1206	Interaction of Electromagnetic Radiation with Media		4	2			2		P		6		6		
KDMF1206	Physics of Condensed Matter		4	2	2				P		6		6		
2.00	**Elective Subjects**		**12**		**4**	**8**			P		**24**		**8**	**16**	
3.00	**Scietific activity**										**60**	**6**	**10**	**14**	**30**
3.01	Scientific and Pedagogical Work										12	4	4	4	
3.02	Research Internship										8				8
3.03.1	Scientific Research and Preparation of the Master's Thesis										35	2	6	10	17
3.03.2	Final State Attestation: Defense of the Master's Thesis										5				5
	total credit hours // Semesterwochenstunden		**36**	**12**	**8**	**12**	**4**				**120**				
										Credit Point		**30**	**30**	**30**	**30**
													120		

Abbreviations: // Abkürzungen
CH = credit hours per week // SWS = Semesterwochenstunden
WS = winter term // Wintersemester
SS = summer term // Sommersemester
Ex/Prü = type of examination // Prüfungsart
CP = credit points (= ECTS-points)
L/V = Lecture // Vorlesung
S = seminar // Seminar
E/Ü = exercise // Übung
LC/Pr = lab course // Praktikum
Pro = project // Projekt
T = certificate // Testat (unbenotet)
P = examination (graded) // benotete Prüfung

Elective disciplines in 70530501 – Physics (Optics and Laser Physics)

	Elective subjects 1 Wahlpflichtkatalog 1		WS	Ex	CP
OPAS2204	Fundamentals of Optoelectronics		2	P	4
OPME2204	Optical Metrology		2	P	4
	1 elective subject amount to		**2**		**4**

	Elective subjects 2 Wahlpflichtkatalog 2		SS	Ex	CP
AMOS2204	Atomic and Molecular Spectroscopy		2	P	4
NANO2204	Nanophysics		2	P	4
	2 elective subjects amount to		**2**		**4**

	Elective subjects 3 Wahlpflichtkatalog 3		SS	Ex	CP
OPSI2304	Optical Signals		2	P	4
LATE2304	Laser Technology		2	P	4
	2 elective subjects amount to		**2**		**4**

	Elective subjects 4 Wahlpflichtkatalog 4		SS	Ex	CP
GUQO2304	Holography and Its Applications		2	P	4
OATZ2304	Optical Communication Systems		2	P	4
	2 elective subjects amount to		**2**		**4**

	Elective subjects 5 Wahlpflichtkatalog 5		SWS	Ex	CP
MOKZ2304	Classical and Modern Foundations of Molecular Optics		2	P	4
SPAN2304	Spectral Analysis		2	P	4
	2 elective subjects amount to		**2**		**4**

	Elective subjects 6 Wahlpflichtkatalog 6		SWS	Ex	CP
NQFA2304	Physical Foundations of Fiber-Optic Devices		2	P	4
LAGE2304	Laser Heterodyning		2	P	4
	2 elective subjects amount to		**2**		**4**

Elective disciplines in 70530501 – Physics (Theoretical Physics)

	Elective subjects 1 Wahlpflichtkatalog 1		SWS	Ex	CP
NFMU2204	Mathematical Methods of Theoretical Physics		2	P	4
KMQB2204	Additional Chapters of Quantum Mechanics		2	P	4
	2 elective subjects amount to		**2**		**4**

	Elective subjects 2 Wahlpflichtkatalog 2		SWS	Ex	CP
AYYR2204	Theory of the Atomic Nucleus and Nuclear Reactions		2	P	4
SONA2204	Scattering Theory		2	P	4
	2 elective subjects amount to		**2**		**4**

	Elective subjects 3 Wahlpflichtkatalog 3		SWS	Ex	CP
KOHN2304	Theory of Condensed States		2	P	4
NOTN2304	Theory of Nonlinear Waves		2	P	4
	2 elective subjects amount to		**2**		**4**

	Elective subjects 4 Wahlpflichtkatalog 4		SWS	Ex	CP
KMNA2304	Quantum Field Theory		2	P	4
STFI2304	Statistical Physics		2	P	4
	2 elective subjects amount to		**2**		**4**

	Elective subjects 5 Wahlpflichtkatalog 5		SWS	Ex	CP
GRNA2304	Theory of Gravitation		2	P	4
RAKO2304	Relativistic Astrophysics and Cosmology		2	P	4

			SWS	Ex	CP
	2 elective subjects amount to		**2**		**4**

	Elective subjects 6 **Wahlpflichtkatalog 6**		**SWS**	**Ex**	**CP**
STMO2304	Standard Model		2	P	4
KVEL2304	Topics in Quantum Electrodynamics		2	P	4
	2 elective subjects amount to		**2**		**4**

Abbreviations: // Abkürzungen
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WS = winter term // Wintersemester
SS = summer term // Sommersemester
Ex/Prü = type of examination // Prüfungsart
CP = credit points (= ECTS-points)
L/V = Lecture // Vorlesung
S = seminar // Seminar
E/Ü = exercise // Übung
LC/Pr = lab course // Praktikum
Pro = project // Projekt
T = certificate // Testat (unbenotet)
P = examination (graded) // benotete Prüfung

The elective subjects hold true as in the fulltime version.

Abbreviations: // Abkürzungen

ILTM1106	Methodology of Scientific Research	
Academic semester	1	ECTS	6

Academic workload

Contact hours		Independent work	
Lectures	26 h	Preparation for classroom activities (review of lecture material, work on seminar topics)	60 h
Practical classes	28 h	Study of literature (solving practical tasks, completing homework assignments)	66 h
Total	54 h	Total	126 h
Total work-load	180 h		

Lecturers

Prof., Dr. Abdurakhmanov Gulmirza

Course content

The significance of research methodology. Science as a socio-cultural phenomenon. Forms of scientific research. Literature analysis. Forms and types of scientific investigations. Types of human activity: reproductive activity; productive activity – their essence and differences. What is creativity? Problem and problem situation in scientific research. Scientific schools: methods and methodological approaches. The concept of a scientific school. Emergence and significance of scientific schools. Professionalization of a scientist and their social responsibility. Choice of research methodology. Categories of scientific research. Reliability of scientific results and ways to ensure it. Regression analysis. Planning of regression experiments. Intellectual property rights. Methodology of dissertation research. Basics of LaTeX. The role of LaTeX in preparing scientific works, its advantages compared to other text editors.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of the meaning and functions of scientific research methodology; forms and types of scientific research; science as a socio-cultural phenomenon; classification of human activities and their specificities; scientific schools and their methodological approaches; principles of choosing research methodology and categories of scientific research; fundamentals of regression analysis and experiment design; opportunities and advantages of LaTeX as a scientific communication tool[1]

- be able to analyze scientific literature and identify current research problems; formulate a research problem and define a problem situation; justify the choice of research methodology; apply regression analysis methods in scientific tasks; prepare scientific texts using LaTeX; consider legal aspects of intellectual property in research[2]

- possess skills in critical analysis of scientific texts; effective application of LaTeX in preparing dissertations and publications; planning and conducting regression experiments; adhering to ethical and legal standards in the research process[3]

    [1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Practical tasks; Self-study; Group work.

Admission requirements

Mandatory: No
Recommended: Computer Science and Information Technology, Basic knowledge of Physics.

Bibliography
1. Shermuxamedova N. A. Ilmiy tadqiqot metodologiyasi. - Toshkent: Innovatsiya ziyo, 2021 - 452 b.
2. Колмогоров Ю.Н., Сергеев А.П., Арапова С.П. Методы и средства научных исследований. Екатеринбург: - Изд-во Уральского университета, 2017.

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	**CA**	**FA**
Timing	8-9 th week	19-20 th week
Form of Assessment	written exam	written and oral exam

Continuous Assessment: conducted after the completion of sections related to lectures and problem-solving amounting to half of the total course content. The covered material will be distributed into examination variants, each containing 3 theoretical questions and 1 practical task. Answers must be submitted in written form. A student can receive up to 5 points for each correct answer.

Final Assessment: conducted on the basis of examination variants covering all topics studied during the course. Each student receives a variant consisting of 3 theoretical questions and 1 practical task on the topics studied throughout the semester. Answers are submitted in written form. After submitting the written part, the student answers the questions orally and may receive up to 5 points for each response. The final grade is calculated as the arithmetic mean of the scores.

Educational Materials and Media Tools

Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

MFOM1106	Methods of Teaching Specialized Disciplines			
Academic semester	1		ECTS	6

Academic workload

Contact hours		Independent work	
Lectures	26 h	Preparation for classroom sessions (review of lecture material, work on seminar topics)	60 h
Seminars	28 h	Study of literature (solving practical tasks, completing homework assignments)	66 h
Total	54 h	Total	126 h
Total work-load	180 h		

Lecturers

Associate Prof., Dr. Begmatova Dilfuza;

Course content

Introduction. Goals and objectives of the course "Methods of Teaching Specialized Disciplines." The significance of regulatory and educational documents in shaping the content of education and teaching. Professional competence of a teacher. Types of class organization in higher education. Specific features of teaching in the higher education system. The use of experiments in teaching physics as an essential methodological component of modern pedagogical technology. The role and significance of teaching aids in the educational process. Educational, instructional, and developmental objectives of teaching. Teaching methods of specialized disciplines based on modern innovative technologies. Teaching with pedagogical software tools. Structure and content of modules. Methods of organizing students' independent learning. Control and assessment of students' academic performance.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of the fundamental laws and formulas studied in specialized disciplines and general physics, as applied in higher education; content and structure of regulatory, legal, and educational documents governing higher education; aims, objectives, and content of the course "Methods of Teaching Specialized Disciplines" and its role in teacher training; modern educational technologies, teaching methods, and forms (including digital, distance, and blended); principles of higher education teaching organization, structure of educational modules, and principles of educational program design; essence and classification of teaching methods (experimental, problem-based, case-methods, project-based, research-oriented); objectives and functions of assessment, evaluation, and reflection in education[1]

- be able to analyze and interpret the content, essence, and didactic significance of physical laws, phenomena, and processes taught in specialized disciplines; apply regulatory documents when designing course content and planning learning activities; justify the choice of educational technologies and methodological approaches in line with course goals; design, organize, and conduct lectures, practicals, labs, and seminars in physics; organize students' independent and research activities; effectively use teaching methods, including digital tools and demonstrations[2]

- possess skills in analyzing teaching methods and adapting them to specific educational contexts; preparing and conducting classes in specialized disciplines using traditional and innovative approaches; designing learning modules, developing teaching materials, and creating individual learning trajectories; determining the limits of applicability of physical laws and models in teaching; applying pedagogical diagnostics, assessment, and

evaluation methods; using digital educational resources and software tools for visualization, modeling, and classroom management[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Seminars; Self-study; Group work.

Admission requirements
Mandatory: No. Recommended: General Pedagogy, Psychology, Methods of Teaching Physics.

Bibliography

1. Ismailova Z.K., Maxsudov P.M., Ergashev O.K., Matkarimov K.J. Maxsus fanlarni o'qitish metodikasi (O'quv qo'llanma). Toshkent – 2018.
2. G'afforov.Y. Maxsus fanlarni o'qitishda yangi pedagogik texnologiyalardan foydalanish usullari // o'quv qo'llanma// T.: "Shafoat nur fayz" 2021. 156 b.
3. Qutbedinov A.K., Toshpulatova Sh.O. Fizika va astronomiya ta'limida tahlil va tadqiqot usullari. Darslik, N.: 2021.
4. Begmatova D.A.,.Qurbonov M., Sodiqova Sh., Abdullayev N.Q., Suvonova O.D. Fizika O'qitish metodikasi. Darslik Toshkent, 2024.
5. Бегматова Д.А. "Методика обучения физике" Ташкент. 2024

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	8-9 th week	19-20 th week
Form of Assessment	written exam	written and oral exam

Continuous Assessment: conducted after the completion of sections corresponding to lectures and seminar sessions, amounting to half of the total course content. The material covered will be distributed into examination variants, each containing 3 theoretical questions. Answers must be submitted in written form. A student can receive up to 5 points for each correct answer.

Final Assessment: conducted on the basis of examination variants covering all topics studied during the course. Each student receives a variant consisting of 3 theoretical questions on the topics covered throughout the semester. Answers are submitted in written form. After submitting the written part, the student answers the questions orally and may receive up to 5 points for each response. The final grade is calculated as the arithmetic mean of the scores.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

FZTU1106	Modern Research Methods in Physics		

Academic semester	1	ECTS	6

Academic workload

Contact hours		Independent work	
Lectures	26 h	**Preparation for classroom and laboratory sessions**	66 h
Laboratory work	28 h	**Literature study**	60 h
Total	54 h	Total	126 h
Total work-load	180 h		

Lecturers

Associate Prof., Dr. Shaymardanov Zafar; Associate Prof., Dr. Jalolov Rivojiddin;

Course content

General part. Fundamentals of modern research methods in physics. Introduction to advanced measuring instruments available at the Institute of Ion-Plasma and Laser Technologies. Atomic Layer Deposition (ALD). Physico-chemical methods for obtaining nanomaterials. Microscopy methods. Electron microscopy, scanning electron microscopy (SEM). Transmission electron microscopy (TEM). Atomic force microscopy (AFM). Fundamentals of modern ultraviolet and visible spectroscopy. Fundamentals of modern fluorescence spectroscopy. Fundamentals of infrared spectroscopy. Fundamentals of modern nonlinear spectroscopy. Fundamentals of Raman spectroscopy. Methods of chromatographic analysis. Ellipsometry method. The role of analytical methods in contemporary scientific research.

Laboratory works. Determination of gas composition using Agilent Technologies GC 7890A gas chromatograph. Measurement of mass spectra of substances using Agilent MSD 5975C – GC 7890A chromatograph–mass spectrometer. Measurement and analysis of Raman scattering spectra using Renishaw InVia Raman spectrometer. Measurement and analysis of infrared spectra using Agilent Technologies Cary 640 Series FTIR spectrometer. Study of material morphology using SOLVER NEXT (NT-MDT) scanning probe microscope. Study of operating principles of TEM LEO 912 AB (ZEISS, Germany) and training in sample preparation. Measurement of nanometer-thin film thickness using SER 850 SENresearch 4.0 spectral ellipsometer (SENTECH).

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of the fundamentals of modern research methods in physics; principles of operation of advanced measuring instruments, including scanning, electron, and atomic force microscopes, and spectrometers; physico-chemical methods for producing nanomaterials; principles of ALD; methods of UV, IR, fluorescence, nonlinear, and Raman spectroscopy; fundamentals of chromatographic analysis and ellipsometry; the role of analytical methods in modern scientific research[1]

- be able to apply physico-chemical methods to analyze and synthesize nanomaterials; operate gas chromatographs, IR and Raman spectrometers; conduct mass spectrometric analysis; analyze material morphology using SEM and TEM; measure thin-film parameters via ellipsometry; interpret experimental data in the context of the applied method[2]

- possess practical skills in operating modern instruments in research and applied contexts; processing and analyzing experimental data; preparing samples for high-precision physical analysis; performing laboratory diagnostics in nanophysics and materials science[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lecture; Laboratory work; Self-study; Group work.
Admission requirements
Mandatory: No
Recommended: Basic knowledge of physics
Bibliography
1. Spectroscopy and Characterization of Nanomaterials and Novel Materials: Experiments, Modeling, Simulations, and Applications /Edited by Prabhakar Misra / Wiley-VCh. 2022. -518 p.
2. Normuradov M.T., Umirzaqov B.E., Tashatov A.Q. Nanotexnologiya asoslari. Toshkent: Yangi nashr, 2020. - 234 bet.
Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	13-14 th week	19-20 th week
Form of Assessment	Written exam or test	written and oral exam

Continuous Assessment: conducted after the completion of sections corresponding to lectures and laboratory work.
a) In the form of examination variants consisting of 2 questions based on the course topics: each question is graded up to 5 points, and the result (MA-1) is determined as the average score of the two questions, rounded up to the nearest whole number. b) In the form of a test: variants consist of 20 questions each, and are graded as follows: 18–20 correct answers $\rightarrow$ 5 points; 14–17 correct answers $\rightarrow$ 4 points; 11–13 correct answers $\rightarrow$ 3 points; 0–10 correct answers $\rightarrow$ 2 points

Final Assessment: conducted in the form of a written examination covering the topics defined in the course syllabus, laboratory assignments, and variants based on self-study topics. . a) Each variant consists of 3 theoretical questions and 1 laboratory-related question, with each question graded up to 5 points. The final score is determined as the arithmetic mean of the question scores. b) In the form of a test: variants consist of 20 questions each, and are graded as follows: 18–20 correct answers $\rightarrow$ 5 points; 14–17 correct answers $\rightarrow$ 4 points; 11–13 correct answers $\rightarrow$ 3 points; 0–10 correct answers $\rightarrow$ 2 points.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials; laboratory setups; measuring instruments and equipment

NTTN1106	Theory of Nonlinear Oscillations and Waves		

Academic semester	1	ECTS	6

Academic workload

Contact hours		Independent work	
Lectures	26 h	Preparation for classroom sessions (review of lecture material, problem solving)	60 h
Problem solving	28 h	Study of literature (solving practical tasks, completing homework assignments)	66 h
Total	54 h	Total	126 h
Total work-load	180 h		

Lecturers

Associate Prof., Dr. Otajonov Sherzod

Course content

Introduction. Phase space, trajectory, flow. Hamiltonian systems. Liouville's theorem. Continuity equation. Generality of mechanisms and regularities of nonlinear oscillatory and wave processes. One-dimensional systems. Harmonic and anharmonic oscillators. Duffing equation. Mathematical pendulum. Limit cycle. Self-oscillations. Weakly nonlinear systems. Exact and approximate methods of integrating equations of motion. Phase analysis. Action–angle variables. Resonance. Nonlinear resonance. Intertwining of phase trajectories. Nonlinear wave processes. Dynamical chaos. Fundamental equations of nonlinear wave processes and their application to physical phenomena. Inverse scattering method. Methods of solving nonlinear dynamical equations. Gelfand–Levitan–Marchenko equation. Reflectionless potentials. One- and two-soliton solutions of the KdV equation. Perturbation theory. Karpman–Maslov theory. Equations with large parameters. WKB approximation. Liouville–Green transformation. Equations with slowly varying coefficients. Numerical methods for solving analytically unsolvable differential equations.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of phase space, phase trajectories and flows; Hamiltonian systems, Liouville's theorem, and continuity equation; fundamental equations and mechanisms of nonlinear oscillatory and wave processes; properties of harmonic, anharmonic oscillators, and pendulum; concepts of self-oscillations, limit cycles, and phase analysis; resonance and nonlinear resonance phenomena; basics of dynamical chaos and trajectory intertwining; perturbation theory, WKB approximation, and the KdV equation[1]

- be able to apply phase and resonance analysis to nonlinear systems; integrate equations of motion using exact and approximate methods; analyze nonlinear wave processes and use governing equations for physical problems; solve inverse scattering problems including the Gelfand–Levitan–Marchenko equation; use action–angle variables in motion analysis; apply numerical methods to analytically unsolvable differential equations[2]

- possess skills in applying phase analysis to complex oscillatory and wave systems; using numerical and analytical methods in professional physics and mathematics; interpreting nonlinear system behavior in terms of chaos, resonances, and solitons; selecting appropriate solution methods depending on the nonlinear problem[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lecture; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Theoretical Mechanics, Methods of Mathematical Physics

Bibliography
1. Dimitri Volchenkov, "Nonlinear dynamics chaos, and complexity", Springer, Switzerland, 2021. 2. Steven H. Strogatz, "Nonlinear dynamics and chaos", CRC Press, 2018.

Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	8-9 th week	19-20 th week
Form of Assessment	written exam	written and oral exam

Continuous Assessment: conducted after the completion of sections corresponding to lectures and problem-solving activities, amounting to half of the total course content. The material covered will be distributed into examination variants, each containing 3 theoretical questions and 1 problem. Answers must be submitted in written form. A student may receive up to 5 points for each correct answer.

Final Assessment: conducted on the basis of examination variants covering all topics studied during the course. Each student is given a variant consisting of 3 theoretical questions and 1 problem on the topics studied throughout the semester. Answers are submitted in written form. After handing in the written part, the student answers the questions orally and may receive up to 5 points for each response. The final grade is calculated as the arithmetic mean of the scores.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

ENMT1206	Interaction of Electromagnetic Radiation with Media		

Academic semester	2	ECTS	6

Academic workload

Contact hours		Independent work	
Lectures	26 h	**Preparation for classroom and laboratory sessions**	66 h
Laboratory work	28 h	**Literature study**	60 h
Total	54 h	Total	126 h
Total work-load	180 h		

Lecturers

Associate Prof., Dr. Akramov Mashrab

Course content

General part. Subject, objectives, and methods of the discipline "*Interaction of Electromagnetic Radiation with Media*". Specifics of electromagnetic wave propagation in different media. Quantization of electromagnetic waves. Einstein's light quantum hypothesis. Planck and Rayleigh–Jeans formulas. Plasma oscillations in solids. Interaction of electromagnetic radiation with plasmons. Interaction of electromagnetic radiation with semiconductors and metals. Modulation spectroscopy. Critical points of the density of states: Van Hove singularities and their manifestations in the optical spectra of semiconductors and metals. Interaction of electromagnetic radiation with gases and liquids. Propagation of light in optical fibers. General theory of light propagation in optical fibers.

Laboratory works. Study of luminescence spectra of rare-earth compounds. Measurement of absorption and excitation spectra of luminescence in rare-earth compounds. Measurement of optical constants of metals using the Drude method. Measurement of double refraction of light in crystals. Investigation of the relative spectral sensitivity of photodetectors.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of the subject, objectives, and methods of studying electromagnetic radiation interaction with media; propagation features of EM waves in different media; fundamentals of EM quantization, Einstein's hypothesis, Planck and Rayleigh–Jeans formulas; plasma oscillations and interaction of EM waves with plasmons; principles of interaction with semiconductors, metals, gases, and liquids; basics of modulation spectroscopy and optical properties of materials at critical points of the density of states; fundamentals of light propagation in optical fibers; physical principles underlying laboratory methods used[1]

- be able to measure and analyze luminescence absorption and excitation spectra; apply the Drude model to determine optical constants of metals; measure birefringence in crystals; investigate spectral sensitivity of photodetectors; interpret optical spectra with regard to electronic states and Van Hove features; analyze light propagation in fiber-optic systems[2]

- possess skills in operating optical instruments in laboratory settings; applying experimental methods in solid-state optics and spectroscopy; processing and interpreting experimental data correctly; using acquired skills in research and applied tasks in radiation physics and optoelectronics[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lecture; Laboratory work; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Basic knowledge of physics

Bibliography
1. Valiev U.V., Pyak P.E., Raxmonov G.T. "Elektromagnit nurlanishning modda bilan ta'sirlashuvi", O'quv qo'llanma, Toshkent, "Universitet", 2022.
2. Dejun Fu, Uygun V. Valiev, Gary W. Burdick, Pavel E. Pyak. "Interaction of electromagnetic radiation with matter", Science Press (Beijing), China 2018.

Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	Written exam or test	written and oral exam

Continuous Assessment: conducted after the completion of sections corresponding to lectures and laboratory work.
a) In the form of examination variants consisting of 2 questions based on the course topics: each question is graded up to 5 points, and the result (MA-1) is determined as the average score of the two questions, rounded up to the nearest whole number. b) In the form of a test: variants consist of 20 questions each, and are graded as follows: 18–20 correct answers → 5 points; 14–17 correct answers → 4 points; 11–13 correct answers → 3 points; 0–10 correct answers → 2 points

Final Assessment: conducted in the form of a written examination covering the topics defined in the course syllabus, laboratory assignments, and variants based on self-study topics. a) Each variant consists of 3 theoretical questions and 1 laboratory-related question, with each question graded up to 5 points. The final score is determined as the arithmetic mean of the question scores. b) In the form of a test: variants consist of 20 questions each, and are graded as follows: 18–20 correct answers → 5 points; 14–17 correct answers → 4 points; 11–13 correct answers → 3 points; 0–10 correct answers → 2 points.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials; Laboratory setups; Measuring instruments and devices

KDMF1206	Physics of Condensed Matter		
Academic semester	2	ECTS	6

Academic workload			
Contact hours		Independent work	
Lectures	26 h	Preparation for classroom sessions (review of lecture material, seminar topics study)	60 h
Seminars	28 h	Study of literature (solving practical tasks, completing homework assignments)	66 h
Total	54 h	Total	126 h
Total work-load	180 h		

Lecturers

Associate Prof., Dr. Ashurov Nurbek

Course content

Classification and fundamental concepts of condensed matter. Interatomic and intermolecular interaction forces. Van der Waals interactions. Disperse media and dispersed phases. Properties of nanophase disperse media. Solid, soft, and liquid condensed matter. General phase diagram of solid, soft, and liquid states. Amorphous and crystalline states in solids. Properties of solid condensed matter. Physical properties of amorphous and crystalline materials. Properties of soft condensed matter. Properties of liquid condensed matter. Formation of liquids and their types. Mechanical and thermal properties of solid-phase media. Reversible and irreversible mechanical and thermal changes in materials. Fluidity and rheological properties of liquid-phase media. Electrophysical processes in condensed matter. Properties of semiconductor condensed matter. Optical and magnetic properties of condensed matter. Relaxation processes in condensed matter.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of the classification and fundamental concepts of condensed matter; interatomic and intermolecular interactions, including van der Waals forces; properties of solid, soft, and liquid condensed matter; phase diagrams of different states of matter; physical properties of amorphous and crystalline materials; properties of nanophase and dispersed media; electrophysical, optical, and magnetic characteristics; the nature of relaxation processes in different condensed matter systems[1]

- be able to analyze mechanical and thermal properties of materials with different phase structures; classify and describe processes in solid- and liquid-phase media; apply knowledge of rheological and fluid properties of liquids in engineering problems; interpret material behavior under reversible and irreversible changes; investigate and describe processes in semiconductor and nanophase media; use physical models to explain optical and magnetic properties[2]

- possess skills in phase and thermodynamic analysis for applied and research tasks; applying experimental and computational methods to study condensed matter properties; analyzing and interpreting data on electrophysical and rheological characteristics of materials; correctly applying acquired knowledge in solid-state physics and materials science tasks[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Seminars; Self-study; Group work.

Admission requirements

Mandatory: No.

Recommended: General Physics

Bibliography
1. Байков Ю.А., Кузнецов В.М., Физика конденсированного состояния. Учебное пособие. Москва 2015. 294 c.   2. Xolmuminov A.A. Polimerlar fizikasi. O'quv qo'llanma. Tashkent. :Universitet. – 2015. -252 b.

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	written exam	written and oral exam

Continuous Assessment: conducted after the completion of sections corresponding to lectures and seminar sessions, amounting to half of the total course content. The material covered will be distributed into examination variants, each containing 3 theoretical questions. Answers must be submitted in written form. A student can receive up to 5 points for each correct answer.

Final Assessment: conducted on the basis of examination variants covering all topics studied during the course. Each student receives a variant consisting of 3 theoretical questions on the topics covered throughout the semester. Answers are submitted in written form. After submitting the written part, the student answers the questions orally and may receive up to 5 points for each response. The final grade is calculated as the arithmetic mean of the scores.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

OPAS2204	Fundamentals of Optoelectronics		

Academic semester	2	ECTS	4

Academic workload

Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Akramov Mashrab

Course content

Optoelectronic semiconductor devices. General characteristics of light detectors and emitters. Photocells and photodiodes. Lasers. Principles of laser operation. Types and classification of lasers. Optical waveguides and their characteristics. Light propagation in planar and channel waveguides. Types of dispersion in optical fibers. Absorption and amplification of light in optical fibers. Light modulators. Methods of controlling optical radiation. Light modulators. Electro-optical deflectors. Optoelectronic sensors. Fiber-optic sensors. Areas of application of optoelectronic sensors. Principles of optical processors. Block diagrams. Physical effects in optical processors and the materials used. Applications of optoelectronic devices. Use of optoelectronic devices in fiber-optic communications, data storage and recording, semiconductor CCD and LCD devices, and other fields.

Learning objectives

Upon successful completion of this course, students should:

- **possess knowledge and understanding** of the types and operating principles of optoelectronic semiconductor devices; the characteristics of photodetectors, photodiodes, lasers, and their classification; the properties and varieties of optical waveguides; the physical principles of light propagation and dispersion in optical fibers; methods of controlling optical radiation (modulation, deflection); the principles of operation of optoelectronic and fiber-optic sensors; physical effects used in optical processors and the materials applied; the main fields of application of optoelectronic devices (CCD, LCD, communication, data storage, etc.)[1]

- **be able to** describe and classify optoelectronic components and systems; analyze processes of modulation, absorption, and amplification of light in waveguides; explain the operation of photoelectric and laser devices; apply principles of optical information processing in practical tasks; select and justify the use of optoelectronic devices for specific technical applications; use block diagrams and physical models to analyze optoelectronic systems[2]

- **acquire skills** in working with optoelectronic devices in laboratory and research settings; applying knowledge to solve engineering and scientific problems in optical communications and photonics; interpreting the characteristics and parameters of optoelectronic components; integrating optoelectronic solutions into complex physical and technical systems[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography
1. Астайкин А.И., Смирнов МК. Основы оптоэлектроники. Саратов:-ВНИИЭФ.2001.-260с.
2. John P. Dakin, Robert G.W. Brown, Handbook of Optoelectronics, Volume I, New York London Taylor & Francis is an imprint of the Taylor & Francis Group, 2018.
3. T.Ahmadjanov, Tebranishlar nazariyasi, Radioelektronika va Optoelektronika asoslari elementlari, O'quv qo'llanma. «Universitet». Toshkent. 2005. - 45 b.

Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

OPME2204		Optical Metrology		
Academic semester		2	ECTS	4

Academic workload				
Contact hours		Independent work		
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).		24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)		60 h
Total	36 h	Total		84 h
Total work-load	120 h			

Lecturers

Associate Prof., Dr. Akhmadjanov Turgunali

Course content

Methods and principles of measuring physical quantities. Concepts and definitions. Optical and quantum methods. Fundamentals of optical elements and devices. Radiation sources. Traditional light sources. Optical elements. Optoelectronic sensors. Operating principles of optoelectronic sensors. Optical devices. Fundamentals of optical metrology techniques and principles. Interferometry. Generation of coherent waves. Interferometers. Holography. Optoelectronic sensors. Moiré method. Polarization. Near-field optics. Practical applications of optical and quantum methods. Angle measurement. Autocollimator. Goniometer. Interferometric testing of prisms. Velocity measurement. Scattering on a moving particle – Doppler shift. Light-scattering-based anemometry. Length measurement. Speckle methods and their applications. Introduction to the speckle effect. Introduction to speckle photography. Speckle displacement interferometry. Tilt measurement. Curvature measurement. Speckle interferometry. Optical surface examination. Flat surface testing. Three-flat calibration method. Spherical surface testing. Interferometer with a scattering plate. Optical coherence. Tomography for industrial applications. Needs and solutions for optical sensor applications in industry. Optical coherence tomography. Industrial applications.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of the basic concepts and principles of measuring physical quantities; optical and quantum measurement methods; the design and operation principles of optical elements and optoelectronic sensors; the principles of interferometers, including speckle interferometry and holography; methods of measuring angle, velocity, length, tilt, and curvature using optical technologies; the fundamentals of optical coherence and its applications in metrology; the principles of optical tomography and its industrial applications; and the use of optical methods for surface characterization[1]

- be able to use interferometric and holographic methods for precision measurements; apply Doppler and anemometric methods for motion and velocity measurement; analyze and interpret results obtained by speckle photography and speckle interferometry; apply optical methods for measuring the geometric parameters of surfaces; use optical coherence tomography in scientific and engineering tasks; select appropriate optical sensors for industrial applications[2]

- acquire skills in working with optical measuring instruments and sensors; calibration and testing of surfaces using interferometric methods; working with coherent optical systems for solving metrological problems; applying these skills in laboratory practice and industrial settings[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography
1. Toru Yoshizawa. Handbook of Optical Metrology: Principle and Applications. Second Edition. CRC Press, 2017.
2. Peter J. De Groot. Optical Metrology. Wiley-VCH. 2004.
3. Оптические измерения / А.Н. АнDreeв, Е.В. Гаврилов, Г.Г. Ишанин и Dr.: учеб. пособие. - М.: Университетская книга; Логос, 2012. - 416 с.

Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	29-30 th week	37-38 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

AMOS2204		Atomic and Molecular Spectroscopy		
Academic semester		2	ECTS	4

Academic workload			
Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Kasimov Abdugappar

Course content

Development of concepts of atomic structure. Bohr's postulates. Electron motion in a centrally symmetric field. Splitting of atomic energy levels. Filling of energy levels. Pauli and Hund's principles. Electron energy in the hydrogen atom. Allowed transitions. Alkali elements and features of their spectra. Violation of central symmetry of the nuclear electric field. Atoms with two s-electrons. Helium atom, spectral structure of atoms with two s-electrons, and their fine structure. Features of rare-earth and transition element spectra. Specifics and multiplet nature of spectra of atoms with partially filled p-, d-, and f-levels. General description of Zeeman splitting. Analysis of spectra by type of magnetic splitting. Analysis of multiplets. Total molecular energy and its components: electronic, vibrational, and rotational energies. Fundamentals of the quantum-mechanical theory of molecules. Vibrations of a one-degree-of-freedom system. Vibrational equation for the harmonic oscillator model, selection rules. Anharmonic vibrations. Rotational structure of vibrational transitions.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of the development of atomic structure theories, including Bohr's postulates and Pauli's and Hund's principles; the structure and splitting of atomic energy levels; features of alkali, rare-earth, and transition element spectra; the nature of allowed transitions and multiplet structure of atomic spectra; features of atoms with two s-electrons (e.g., helium) and their spectral properties; the Zeeman effect and classification of magnetic splittings; the quantum-mechanical foundations of molecular spectra (electronic, vibrational, rotational energies); selection rules and features of harmonic and anharmonic oscillations[1]

- be able to analyze and interpret atomic and molecular spectra; apply the laws of quantum mechanics to describe spectral transitions; distinguish spectrum types by structure and level splitting; classify energy levels and multiplets; describe vibrational-rotational spectral structures; explain features of complex atom spectra with partially filled p-, d-, and f-shells[2]

- acquire skills in using spectral data to determine atomic and molecular characteristics; applying spectral analysis in applied and experimental work; constructing and analyzing energy level and transition schemes; using spectroscopic knowledge to solve scientific and engineering problems in physics and materials science[3]

   [1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography
1. Bardhan A., et al. «Spectroscopy», Uttarakhand Open University, Haldwani, 2022. 311p.
2. Елишевич М.А. «Атомная и молекулярная спектроскопия», издание второе, М., Эдиториал УРСС, 2001 г.

Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

NANO2204	Nanophysics		
Academic semester	2	ECTS	4

Academic workload			
Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Prof., Dr. Abdurakhmonov Gulmirza; Prof., Dr. Shoislomov Ulugbek

Course content

History of nanotechnology, its stages of development, and physical foundations. Elements of solid-state physics. Free electron theory. Nanomaterials. Fullerenes, carbon nanotubes, and graphene. Quantum size effects. Quantum confinement. Fundamental electronic phenomena in nanostructures. Band diagrams for different semiconductor material pairs. Inversion layers in silicon structures. Metal – insulator – semiconductor (MIS or MOS) transistors. Heterostructures. Quantization in a one-dimensional (1D) electronic system. Density of states. Ballistic transport. Resistance of ballistic conductors. Nanotube resistance. Zero-dimensional (0D) electronic structures. Resonant tunneling. Single-electron transistor. Resonant-tunneling transistor based on quantum dots. Quantum tunneling effect. Surface plasmon resonance (SPR). Total internal reflection of light. Localized plasmon resonance. Elements of nanophotonics. Photonic band gap. Photonic crystals.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of the stages of nanotechnology development and their physical foundations; quantum size effects and quantum confinement phenomena in nanostructures; the physics of nanomaterials, including fullerenes, carbon nanotubes, and graphene; the principles of MIS/MOS structures, heterostructures, and single-electron transistors; features of ballistic transport and resistance in nanoconductors; quantum and resonant tunneling phenomena; fundamentals of plasmon resonances (surface and localized); and the basic concepts of nanophotonics, including photonic crystals and photonic band gaps[1]

- be able to analyze electronic processes in nanoscale structures; construct band diagrams and explain carrier behavior in semiconductor nanosystems; apply density of states models for one-dimensional and zero-dimensional structures; interpret physical effects in nanophotonic devices; evaluate the influence of quantum effects on material and device properties; apply plasmon phenomena to describe light–nanostructure interactions[2]

- acquire skills in calculating energy characteristics of nanostructures; applying knowledge of quantum effects in solving practical problems in nanoelectronics and nanophotonics; using concepts of quantum tunneling in applied research; integrating nanophysics approaches in the design and modeling of nanoscale devices[3]

    [1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Molecular Physics

Bibliography
1. Вартанян Т.А. Основы физики металлических наноструктур. С.-Петербург: ИТМО, 2013. 2. Ryndyk D.A. Theory of Quantum Transport at Nanoscale. An Introduction. –New York: Springer, 2016. 3. Nouailhat A. An Introduction to Nanoscience and Nanotechnology. – Hoboken: Wiley, 2008. 4. Trügler A. Optical Properties of Metallic Nanoparticles. Basic Principles and Simulation. – New York: Springer, 2016.

Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

OPSI2304	Optical Signals		
Academic semester	3	ECTS	4

Academic workload			
Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Vildanov Ramil

Course content

Introduction. Basic concepts. Purpose and objectives of the course, its relation to other branches of physics, challenges in studying the subject. Signal analysis. Spectral analysis of signals: Fourier series for periodic signals. Fourier analysis of non-periodic signals. Processes with a constant (white) spectrum. Correlation function of signals. Optical signals. Complex representation of signals, analytic signal in optics. Optical signal processing. Transformation of the light field in a lens. Coherent properties of optical radiation. Temporal and spatial coherence of light, model of a random light field. Coherence of radiation from different sources. Coherence and radiation properties. Fourier optics. Transformation of optical fields during propagation in space. Fresnel diffraction. Fraunhofer diffraction and Fourier transformation. Functional transformations in optical systems. Functional diagram of an optical system. Wavefront formation in a lens. Optical transformations in a lens system. Optical signal detection. General block diagram and operating methods of optoelectronic devices. Characteristics of photodetectors. Heterodyne detection. Photon detection. Statistics of photoelectron counts, Mandel's formula.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge and understanding of the fundamental concepts and goals of the discipline and its relation to other branches of physics; methods of spectral and correlation signal analysis, including Fourier transforms; complex and analytic representations of optical signals; physical foundations of light coherence (temporal and spatial); fundamentals of Fourier optics and optical signal processing; principles of Fresnel and Fraunhofer diffraction; functional diagrams of optical systems; characteristics of photodetectors and photon-counting statistics[1]

- be able to analyze optical signals using Fourier transforms; apply correlation methods to evaluate radiation properties; describe propagation and transformation of light fields in optical systems; determine coherence properties of various light sources; interpret detection schemes of optical signals; use heterodyne and direct detection methods[2]

- acquire skills in working with analytical representations of optical signals; applying optical transformations in image and signal processing; using photodetection devices for recording and analyzing optical information; applying statistical methods to analyze photoelectron processes, including the use of Mandel's formula[3]

   [1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. Ахманов С.А., Никитин С.Ю. Физическая оптика: Учебник. Москва: МГУ; Наука, 2004.-656с.(эв)
2. Vanderlugt A.. Optical Signal Processing. North Carolina State University, 1992. 604p.(эв)
3. Оптические измерения / А.Н. АнDreeв, Е.В. Гаврилов, Г.Г. Ишанин и Dr.: учеб. пособие. — М.: Университетская книга; Логос, 2008. 416 с. (эв)
4. Вильданов Р.Р., Эшонкулов Ғ.Б. Оптик нурланишнинг когерентлик эффектлари.: Ўқув қўлланма. -Т.: "Университет". 2009. 68b.

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	10-11 th week	19-20 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

LATE2304		Laser Technology		

Academic semester		3	ECTS	4

Academic workload

Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Shaymardanov Zafar

Course content

Laser technologies used in metrology, chemistry, biology, and medicine. Communication systems. Elements of fiber-optic communication systems. Integrated optical systems. Laser technologies in optoelectronic systems. Laser spectroscopy. Nonlinear laser spectroscopy. Applications of laser technologies in industry. Laser cutting. Laser marking. Laser welding.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the principles of operation and areas of application of lasers in science and technology; features of using laser technologies in metrology, chemistry, biology, and medicine; structure of fiber-optic and integrated optical communication systems; principles of optoelectronic systems based on lasers; fundamentals of laser and nonlinear laser spectroscopy; technological processes of laser cutting, welding, and marking; features of laser–material interaction; safety requirements for working with laser systems[1]

- be able to analyze the physical principles of laser and optical systems; select laser equipment according to specific technological tasks; apply laser spectroscopy methods in scientific research; evaluate the efficiency of laser technological processes; use components of fiber-optic communication systems; design and describe integrated optical circuits using lasers[2]

- acquire skills in safe operation of laser equipment in laboratory and industrial environments; performing basic laser material processing operations (cutting, welding, marking); conducting spectral analysis using laser sources; applying laser technologies in solving applied problems across various fields of science and engineering[3]

    [1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements

Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. Ахманов С.А., Никитин С.Ю. Физическая оптика: Учебник. Москва: МГУ; Наука, 2004.-656с.(эв)
2. Vanderlugt A.. Optical Signal Processing. North Carolina State University, 1992. 604p.(эв)
3. Оптические измерения / А.Н. АнDreeв, Е.В. Гаврилов, Г.Г. Ишанин и Dr.: учеб. пособие.

— М.: Университетская книга; Логос, 2008. 416 с. (эв)
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Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	10-11 th week	19-20 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

GUQO2304		Holography and Its Applications		
Academic semester		3	ECTS	4

Academic workload

Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Ramazanov Asror

Course content

Introduction. Basic concepts. Main characteristics of objects used in holography. Physical foundations of the holography method. Radiation sources for holography. Temporal and spatial coherence of light. Coherence of radiation from various sources. Types of holograms and their features, holographic schemes. Dynamic and resonant holography. Formation of holograms. Wave reconstruction. Basic concepts and equations of holography. Counter-wave hologram. Possible applications of the Denisyuk scheme. Leith–Upatnieks scheme and its features. Types of holograms: Gabor, Denisyuk, Benton, Fresnel, Fraunhofer, Fourier. Image formation in holography. Analysis of hologram characteristics. Properties of holograms of a point source. Recording amplitude and phase of a point image. Holography of moving objects. Acoustic holography. Reconstruction of three-dimensional images. Digital holography and holographic interferometry. Methods and principles of digital holography. Holographic interferometry and digital holography.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the physical foundations of holography and coherence conditions; principles of hologram formation, recording, and reconstruction; types of holograms (Gabor, Denisyuk, Benton, Fresnel, Fraunhofer, Fourier) and their features; main holographic schemes (Denisyuk, Leith–Upatnieks, etc.); features of dynamic, resonant, acoustic, and digital holography; methods of recording amplitude and phase of the wavefront; fundamentals of holographic interferometry; applications of holography in science, technology, and industry[1]

- be able to select radiation sources and optical schemes for hologram recording; analyze and compare different types of holograms; reconstruct object images from holograms; apply holographic interferometry for diagnostics of deformations and vibrations; interpret spatial characteristics of holographic images; use digital holography methods for recording and processing three-dimensional images[2]

- acquire skills in recording and reconstructing holograms using coherent radiation; applying holographic methods in optical measurements and visualization; using digital algorithms for hologram processing; applying holographic technologies in professional and scientific activities[3]

   [1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. Ramazanov A.X. "Golografiya va uning qo'llanilishi" O'quv qo'llanma. Toshkent, "Ma'rifat" 2023. 122 bet.
2. Ландсберг Г.С. "Оптика" Т 1981.
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4. В.М.Гинзбург, Б.М.Степанов–«Голографические измерения», М., «МИР», 1985г.
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Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	10-11 th week	19-20 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

OATZ2304	Optical Communication Systems		
Academic semester	3	ECTS	4

Academic workload				
Contact hours		**Independent work**		
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).		24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)		60 h
Total	36 h	Total		84 h
Total work-load	120 h			

Lecturers

Associate Prof., Dr. Akhmadjanov Turgunali

Course content

Objectives of the course *Optical Communication Systems* and its relation to other study areas. Optical fibers. Geometry, manufacturing, and types of optical fibers. Wave propagation and absorption in optical fibers. Nonlinear effects. Optical transmitters. Basic concepts, light-emitting diodes, semiconductor lasers, noise, and dynamics. Optical receivers. Photodetectors: photodiodes, photomultiplier tubes. Noise and receiver sensitivity. Optical amplifiers. Semiconductor optical amplifiers, Raman and doped-fiber amplifiers, amplifier noise. Introduction to solitons. Optical solitons. Propagation of solitons in optical fibers.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the principles of operation of optical communication systems and their role in telecommunications; geometry, types, and physical foundations of optical fibers; mechanisms of wave propagation, dispersion, and absorption in fibers; design and operating principles of optical transmitters (LEDs, lasers) and receivers (photodiodes, PMTs), as well as their noise characteristics; operating principles of optical amplifiers (semiconductor, Raman, erbium-doped); fundamentals of nonlinear effects and soliton propagation in optical fibers; influence of noise on signal transmission quality[1]

- be able to select optical communication components for specific tasks; analyze parameters and transmission characteristics in fibers; calculate losses, sensitivity, and gain in optical systems; apply physical models to describe soliton propagation; interpret the influence of nonlinear effects on signals; evaluate system noise immunity and optimize equipment configuration[2]

- acquire skills in configuring and testing basic elements of fiber-optic communication lines; diagnosing and minimizing transmission losses; using knowledge of solitons for analyzing signal transmission stability; integrating optical transmitters, receivers, and amplifiers into a unified telecommunication system[1]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements

Mandatory: No

Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. "Fiber-Optic Communication Systems" van G.P. Agrawal, Wiley series in Microwave and

Optical Engineering, 2010, 4td edition. 2. "Optical fiber communication systems: Theory and Practice with Matlab and Simulink models", Le Nguyen Binh, CRC Press, Taylor & Francis Group 2010.		

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	10-11 th week	19-20 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools

Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

MOKZ2304	Classical and Modern Foundations of Molecular Optics

Academic semester	3	ECTS	4

Academic workload

Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (review of lecture material, seminar topics study)	24 h
Seminars	18 h	Study of literature (solving practical tasks, completing homework assignments)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Prof. Dr. Otajonov Shavkat

Course content

Subject, purpose, and objectives of the discipline *Classical and Modern Foundations of Molecular Optics*. Achievements and challenges. Limitations of existing theories and experimental methods. Properties of media and molecules. Molecular polarization, polarizability tensor and its properties. The role of physical parameters in analyzing the structure of media. Regularities of molecular and atomic transitions between energy levels. Molecular light scattering in media. Raman scattering of light in media. Key physical parameters of radiation spectra. Classical and modern theories of radiation spectra. Experimental devices for spectroscopic studies. The role of the instrumental function in spectroscopy. Requirements for light sources in spectroscopy.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the subject, purpose, and objectives of molecular optics; physical properties of molecules and media, including polarization and polarizability tensors; principles of molecular and Raman light scattering; structure of molecular energy levels and transitions; classical and modern theories of radiation spectra; characteristics of light sources used in spectroscopy; the effect of the instrumental function on measurements; major limitations and challenges of theoretical and experimental approaches[1]

- be able to apply tensor analysis to describe molecular polarizability; analyze light scattering in various physical media; interpret spectra with regard to radiation and medium parameters; select and adjust spectroscopic equipment for research tasks; justify the choice of light sources and experimental conditions; use physical parameters of media to analyze their structure[2]

- acquire skills in practical work with spectroscopic equipment; applying vector and tensor methods in processing molecular optics data; interpreting and analyzing experimental spectra; properly accounting for the instrumental function in measurements[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Seminars; Self-study; Group work.

Admission requirements

Mandatory: No.

Recommended: Optics, Quantum Mechanics

Bibliography

1. Xabibullaev P.Q., Bulavin L.A., Pogorelov V.Ye., Tuxvatullin F.X., Lizengevich A.I., Otajonov Sh., Jumaboev A. Dinamika molekul v jidkostyax. Tashkent, "Fan", 2009, 410 b.

2. Yelyashevich M.A. Atomnaya i molekulyarnaya spektroskopiya. M., "Nauka", 2001, 894 b.
3. Eshchanov B., Otajonov Sh. Kolebatelnaya i vrashatelnaya spektroskopiya molekul v jidkoy faze. Tashkent, 2019, 178 b.

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	written exam	written and oral exam

Continuous Assessment: conducted after the completion of sections corresponding to lectures and seminar sessions, amounting to half of the total course content. The material covered will be distributed into examination variants, each containing 3 theoretical questions. Answers must be submitted in written form. A student can receive up to 5 points for each correct answer.

Final Assessment: conducted on the basis of examination variants covering all topics studied during the course. Each student receives a variant consisting of 3 theoretical questions on the topics covered throughout the semester. Answers are submitted in written form. After submitting the written part, the student answers the questions orally and may receive up to 5 points for each response. The final grade is calculated as the arithmetic mean of the scores.

Educational Materials and Media Tools

Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

SPAN2304	Spectral Analysis		
Academic semester	3	ECTS	4

Academic workload		
Contact hours		**Independent work**
Lectures	18 h	**Preparation for classroom sessions (review of lecture material, seminar topics study)**	24 h
Seminars	18 h	Study of literature (solving practical tasks, completing homework assignments)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Prof. Dr. Eshchanov Bakhodir

Course content

The role of the discipline *Spectral Analysis* in practice, science, and engineering. Fundamentals of spectral analysis: atomic emission analysis. Determination of elemental composition using atomic spectra. Absorption and fluorescence analysis. Molecular spectral analysis. Luminescence. Scattering spectra. Types and main characteristics of spectral instruments for atomic emission. Sensitivity limits for electromagnetic spectra. Preparation of experimental setups for measurements. Requirements for optical parts of experimental devices. Methods of recording electromagnetic spectra. Causes of atomic spectral line broadening. Qualitative and quantitative analysis based on atomic emission spectra. Determination of wavelength in atomic spectra. Relationship between optical density of absorption spectra and emission intensity. Determination of composition and quantity of elements in substances (samples). Three-standard method. Molecular spectral analysis. Study of medium structures using scattering spectra. Determination of natural vibrational frequencies of atoms from scattering spectra. IR spectroscopy. Luminescence analysis.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the role and significance of spectral analysis in science, engineering, and applied practice; fundamentals of atomic emission and molecular spectral analysis; physical principles of luminescence, fluorescence, and scattering spectra; design and characteristics of spectral instruments; mechanisms of atomic line broadening; principles of IR spectroscopy and luminescence analysis; relationship between optical density and emission intensity[1]

- be able to determine elemental composition of substances from atomic and molecular spectra; perform qualitative and quantitative spectral analysis; determine wavelength and intensity of spectral lines; analyze scattering spectra to study material structures; use the three-standard method for quantitative analysis; prepare experimental setups and adjust optical components of spectroscopic instruments[2]

- acquire skills in recording and interpreting electromagnetic spectra; working with atomic emission and molecular spectrometers; evaluating sensitivity limits and resolving power of instruments; calculating and analyzing vibrational frequencies from scattering spectra; applying IR spectroscopy and luminescence analysis in practice; selecting experimental methods and analyzing processes using spectral approaches[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Seminars; Self-study; Group work.
Admission requirements
Mandatory: No.
Recommended: Atomic Physics, Optics, Quantum Mechanics
Bibliography
1. Степанов В.И. Введение в современную оптику: поглощение и испускание света квантовыыми системами, Минск , 1991.
2. Скоков И.В. Оптические спектральные приборы, М.1984.
3. Айвазова А.А., Валиев У.В., Мухамедханова Ш.И., Отажонов Ш., Ясколко В.Я. Спецпрактикум по оптике и спектроскопии. Т.2005.
4. Нагибина И.М., Прокофьев В.К. Спектральные приборы и техника спектроскопии, М.1963.
Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	written exam	written and oral exam

Continuous Assessment: conducted after the completion of sections corresponding to lectures and seminar sessions, amounting to half of the total course content. The material covered will be distributed into examination variants, each containing 3 theoretical questions. Answers must be submitted in written form. A student can receive up to 5 points for each correct answer.

Final Assessment: conducted on the basis of examination variants covering all topics studied during the course. Each student receives a variant consisting of 3 theoretical questions on the topics covered throughout the semester. Answers are submitted in written form. After submitting the written part, the student answers the questions orally and may receive up to 5 points for each response. The final grade is calculated as the arithmetic mean of the scores.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

NQFA2304	Physical Foundations of Fiber-Optic Devices		
Academic semester	3	ECTS	4

Academic workload			
Contact hours		**Independent work**	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Akhmadjanov Turgunali

Course content

Propagation of electromagnetic waves in dielectric media. Wave equation. Dielectric permittivity tensor. Refractive index, absorption coefficient. Phase and group velocity. Metallic fibers. Optical approximation. Propagation modes. Evanescent waves. Light propagation in metallic fibers. Dispersion equation. Inhomogeneous waves. Complex amplitudes. Dielectric fibers. Critical frequencies. Principles of single-mode and multimode propagation. Wave packet broadening. Reflection of plane waves at the interface of two media. Fresnel equations. Dispersion equation. Phase-matching condition. Classification of fiber-optic devices. Modes. Types of optical fibers. Main physical properties of fibers. Functional elements of fiber optics. Optical isolators. Coupling and splitting filters. Modulators. Frequency shifters. Fiber-optic transmitters and receivers. Internal photoelectric effect. LEDs and photodiodes. Semiconductor lasers. Applications of fibers in fiber-optic systems. Fiber-optic sensors. Gyroscopes. Optical communication systems.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the physical principles of electromagnetic wave propagation in dielectrics and metals; the wave equation, dielectric permittivity tensor, phase and group velocities; dispersion equations, modes, and phase-matching conditions; types of optical fibers and their physical properties; principles of single-mode and multimode propagation; Fresnel equations and reflection at interfaces; physical principles of LEDs, photodiodes, and semiconductor lasers; classification and purpose of fiber-optic devices[1]

- be able to apply wave optics equations to describe processes in fibers; analyze light propagation in various types of fibers; calculate critical frequencies and dispersion relations; determine conditions for single-mode and multimode propagation; describe the operation of fiber-optic modulators, filters, isolators, and sensors; apply optical laws to calculate reflection and refraction; analyze the performance of optical gyroscopes and communication systems[2]

- acquire skills in applying the mathematical framework of wave optics and tensor descriptions; calculating and modeling modes in fiber structures; using fiber-optic elements in engineering and scientific applications; applying fiber-optic devices for signal transmission and detection; experimental work with transmitting and receiving devices, including lasers and photodiodes; analyzing and optimizing the physical parameters of fiber-optic systems[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work
Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

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2. Д.Маркузе. Оптические волноводы. Изд-во Мир, М.1974
3. В.Глазер. Световодная техника М.Энергоатомиздат, 1985.
4. Ландсберг Г.С. Оптика, 1984.

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	**CA**	**FA**
Timing	10-11 th week	19-20 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools

Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

LAGE2304	Laser Heterodyning		
Academic semester	3	ECTS	4

Academic workload

Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Vildanov Ramil

Course content

Principles of heterodyne detection. Concept of heterodyning, interference at different frequencies. Optical heterodyning: optical mixing, heterodyne photocurrent. Main characteristics of heterodyne signals. Spectrum of heterodyne signals. Formation of heterodyne signal spectra. Heterodyning of modulated fields. Heterodyning of random signals. Beam matching in heterodyning. Spatial matching of fields in heterodyning: wavefront matching. Conditions of heterodyning. Misalignment angle. Effective area of heterodyne photodetectors. Effective aperture area. Siegman's theorem. Effective area in receiver schemes. Wavefront-matching schemes. Laser heterodyning and interferometry. Capabilities of laser interferometry. Two-frequency laser systems. Frequency-modulated interferometers. Sensitivity limits of laser interferometers. Heterodyne interferometers. Analysis of measurement signals. Heterodyne phase metrology. Dual-laser deformographs. Heterodyning efficiency. Heterodyne measurement methods. Optical frequency-shifting techniques in laser systems. Heterodyne photodetectors. Methods of laser spectroscopy. Spectral measurements with heterodyne detection. Optical mixing spectroscopy. Remote sensing. Practical schemes.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the physical principles of heterodyne detection and interference at different frequencies; principles of optical mixing and characteristics of heterodyne signals; spectra of heterodyne signals, including random and modulated fields; methods of spatial and wavefront matching in heterodyning; principles of constructing heterodyne interferometers and their sensitivity; designs of heterodyne photodetectors and measurement schemes; principles of optical mixing spectroscopy and remote sensing[1]

- be able to analyze the formation of heterodyne signals and their spectra; calculate parameters of heterodyne photocurrent and effective receiver areas; apply heterodyne wavefront-matching schemes and evaluate misalignment angles; use two-frequency laser systems and frequency-modulated interferometers; perform heterodyne measurements of deformations and phase shifts; implement frequency-shifting methods and laser spectroscopy techniques[2]

- acquire skills in practical adjustment of heterodyne optical schemes and interferometry systems; selecting and matching laser sources and photodetectors for heterodyne applications; interpreting spectral data obtained by heterodyne detection; constructing and using heterodyne systems for remote sensing; implementing practical schemes of high-sensitivity heterodyne measurements; applying vector and tensor methods to describe optical fields and signals[3]

^{1} knowledge; ^{2} skills; ^{3} abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography
1. V. Protopopov. Laser Heterodyning. Berlin Heidelberg: Springer-Verlag, 2009. -355p.
2. Koronkevich V.P., Sobolev V.S., Dubnищev Yu.N. Lazernaya interferometriya. Novosibirsk: Nauka, 1983.-213s.
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Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	10-11 th week	19-20 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

NFMU2204		Mathematical Methods of Theoretical Physics		
Academic semester		2	ECTS	4

Academic workload				
Contact hours		Independent work		
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).		24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)		60 h
Total	36 h	Total		84 h
Total work-load	120 h			

Lecturers
Associate Prof., Dr. Fayzullayev Biruni

Course content

Analytical theory of vector algebra. Precise mathematical definitions of vectors and tensors. Operations with them. Eigenvectors and eigenvalues. Matrix diagonalization. Types of matrices and their properties. Examples of eigenvalue problems. Which matrices can be diagonalized and their physical meaning. Transforming an arbitrary complete system into an orthonormal form using the Gram–Schmidt method. Alternative approaches to orthonormal systems and orthogonal polynomials. Classification of ordinary differential equations by types of singular points. Solutions near an ordinary point. Method of expanding the solution of a differential equation into a series near a point. Concepts of ordinary and singular points. One, two, and three regular singular points. General form of solutions near a regular singular point. Solutions near an irregular point. Hypergeometric and generalized hypergeometric equations and their solutions. Integral representations. Derivation of special functions frequently encountered in mathematical physics from the hypergeometric function. Approximate methods for evaluating integrals: Laplace's method, methods for asymptotic evaluation of integrals, the saddle point method, and the method of stationary phase. Main asymptotic techniques most commonly used in theoretical physics. Group, subgroup, cosets, homomorphism, isomorphism, and Dr. Group representations. Schur's lemmas. Types of representations. Schur's lemmas. Orthogonality relations. Direct product. Selection rules. Reducibility and irreducibility of representations. Forbidden and allowed processes. The SU(2) group and its representations. Classification of continuous groups. Construction of SU(2) group representations. SU(2) spinors. Properties of spinors in quantum mechanics. Angular momentum addition. Multiplication rules of representations. Addition of spin and orbital angular momentum. Lorentz group. Main properties of the Lorentz group, its generators and algebra. Relativistic spinors.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of scalar and vector fields, their mathematical description and physical interpretation; rigorous definitions of vectors and tensors, their algebraic properties and operations; the notions of eigenvalues and eigenvectors and the physical meaning of matrix diagonalization; the classification of ODE singular points and methods for constructing solutions near them; properties of hypergeometric and generalized hypergeometric equations and their role in physics; approximate methods for evaluating integrals (Laplace, stationary phase, saddle point); fundamental concepts of group and representation theory (groups, subgroups, cosets, homomorphisms, isomorphisms, Schur's lemmas); the structure and properties of the SU(2) group and its application in

quantum mechanics; the construction and properties of the Lorentz group, its generators, algebra, and relativistic spinors[1]

- be able to apply vector and tensor analysis to solving physical, technical, and engineering problems; compute eigenvalues and eigenvectors of matrices and interpret them physically; apply the Gram–Schmidt method and analyze orthogonal polynomials; classify and solve ODEs with regular and irregular singular points; derive and apply special functions from hypergeometric equations; construct and apply representations of finite and continuous groups (in particular, SU(2)) in physics; employ asymptotic methods in approximate calculations of physical quantities; analyze symmetries of physical systems and apply selection rules[2]

- acquire skills in working with vector, tensor, and matrix objects in theoretical physics problems; performing spectral analysis of linear operators and diagonalization of matrices; applying differential equations with singular points for modeling physical processes; deriving and using hypergeometric and special functions in physical calculations; implementing asymptotic methods in theoretical physics problems; applying group representation theory in quantum and relativistic physics; constructing and interpreting SU(2) and Lorentz spinors for the description of quantum particles and fields[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography
1. Fayzullaev B.A. Nazariy fizikaning metematik usullari, Toshkent, "Barkamol fayz media" nashriyoti, 2016 yil.
2. Mathematical Methods of Theoretical Physics, Karl Svozil, World Scientific, 2020
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Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

KMQB2204		Additional Chapters of Quantum Mechanics		
Academic semester		2	ECTS	4

Academic workload			
Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Fayzullayev Biruni

Course content

Quantum theory of angular momentum and spin. Rotational symmetry and the operator of total angular momentum. General formalism of angular momentum. Addition of angular momenta, Clebsch–Gordan coefficients. Spin, spin operator. Wave function of particles with spin. Motion of a free electron in a constant magnetic field. Landau levels. Transformation of angular momentum wave functions under rotation of the coordinate system. Wigner D-functions. Quantization of rigid body rotation. D-functions as rotational wave functions of the rigid rotator. Wigner–Eckart theorem. Systems of identical particles. Complex atom. Indistinguishability of identical particles in quantum mechanics. Fermions and bosons. Exchange interaction in a two-electron system. Excited states of the helium atom. Exchange splitting of configuration energies. Complex atom. LS-coupling. Hund's rules. Fine structure. Zeeman effect in hydrogen and in complex atoms. Hyperfine structure of atomic levels. Second quantization method. System of identical particles in the representation of second quantization. Fock space. Creation and annihilation operators. Representations in the second quantization method. Operators in the second quantization formalism. Second-quantized Schrödinger equation. Hartree–Fock equation. Quantization of crystal lattice vibrations. Interaction of electromagnetic field with matter. Quantization of the electromagnetic field, photons. Emission and absorption of photons by atomic electrons. Spontaneous and stimulated emission. Direct and reverse transitions. Electric dipole approximation. Berry phases. Adiabatic evolution and geometric phase. Berry connection for spin systems and Bloch states in a crystal. Relation to motion in a lattice potential: anomalous velocity of a wave packet. Feynman path integral. Path integral for the transition amplitude $K(x,x')$ and the Schrödinger equation. Factorization of the solution for $K(x,x')$ for quadratic potentials. Explicit calculation for free motion and for the harmonic oscillator (with prefactor). Evaluation of functional determinants by the Gelfand–Yaglom method.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of scalar and vector fields, their mathematical description and physical interpretation; quantum theory of angular momentum and spin, rotational symmetries and the formalism of total angular momentum; angular momentum addition rules and Clebsch–Gordan coefficients; Wigner D-functions, the Wigner–Eckart theorem, and quantization of rotational motion; principles for describing systems of identical particles (fermions, bosons, wave function symmetries); structure of complex atoms, including LS-coupling, Hund's rules, level splitting, Zeeman effects; fundamentals of second quantization: creation and annihilation operators, Fock space, second-quantized equations; interaction of radiation with matter (photons, emission, dipole approximation);

the concept of Berry phase and geometric phase; the path integral formalism and its connection with the Schrödinger equation[1]

- be able to apply vector and tensor analysis in solving problems of quantum field theory, atomic and nuclear physics; use quantum mechanical formalism to describe and quantize angular momentum; analyze the behavior of spin particles in magnetic fields, determine Landau levels and compute observables; apply the Wigner–Eckart theorem and Wigner D-functions to symmetry problems; describe states of identical particle systems and calculate exchange interactions; employ second quantization to describe many-particle systems; analyze radiation and absorption processes in atomic systems (including dipole transitions); apply Berry phase formalism to analyze geometric phases in quantum systems; use path integral techniques to calculate transition amplitudes and relate them to wave mechanics[2]

- acquire skills in mathematically describing physical quantities with vector and tensor objects in quantum mechanics; computing Clebsch–Gordan coefficients and constructing wave functions with given angular momentum; analyzing atomic spectra with fine and hyperfine structure; constructing and interpreting second-quantized equations for many-particle systems; calculating transition probabilities using operator formalism; evaluating geometric phases and interpreting their physical significance in spin and crystalline systems; applying the path integral formalism, including factorization and the Gelfand–Yaglom method, in problems with quadratic Lagrangians[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. Ландау, Л. Д. Теоретическая физика / Л. Д. Ландау, Е. М. Лифшиц. - 5-е изд., стер. – Москва : ФИЗМАТЛИТ, [б. г.]. - Том 3 : Квантовая механика (нерелятивистская теория) - 2001. - 808 с. - ISBN 5-9221-0057-2: https://e.lanbook.com/book/2380.
2. Мессиа, А. Квантовая Механика. Т.1. / А. Мессиа — М.: Наука, 1978.
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6. Варшалович, Д., Херсонский В., Орленко Е., Москалёв, А. Квантовая теория углового момента и её приложения. Москва : ФИЗМАТЛИТ, 2017.
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8. Р. Фейнман, А. Хиббс, «Квантовая механика и интегралы по траекториям»

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to

lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

AYYR2204	Theory of the Atomic Nucleus and Nuclear Reactions

Academic semester	2	ECTS	4

Academic workload

Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Fayzullayev Biruni

Course content

Fundamental concepts of nuclear physics: atomic nucleus, nucleons, isotopes, isobars, isotones. Strong and weak interactions. Radioactivity: α-, β-, γ-decays. Half-life. The liquid drop model of the nucleus. Main postulates of the liquid drop model. Weizsäcker formula. Relation between nuclear binding energy and nuclear mass. Nuclear stability. Shell model. Quantum-mechanical description of the nucleus. Nuclear potentials: square well, optical, and shell potentials. Quantum numbers of nucleons: principal quantum number, orbital angular momentum, spin. Magic numbers. Stability of magic nuclei. Nuclear reactions. Main types of nuclear reactions: capture, scattering, decay. Conservation of energy and momentum in nuclear reactions. Threshold energy. Nuclear reaction cross section. Examples of nuclear reactions: fission, fusion of light nuclei.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the fundamental concepts of nuclear physics, including the structure of the atomic nucleus, nucleon properties, distinctions between isotopes, isobars, and isotones; the nature of strong and weak interactions and their role in nuclear stability and radioactive processes; mechanisms and types of radioactive decay (α, β, γ); the physical basis of the liquid drop model, the Weizsäcker formula, and its significance for binding energy evaluation; the shell model and nucleon distribution across energy levels, magic numbers; quantum-mechanical properties of nuclear states (spin, orbital numbers, total angular momentum); types of nuclear reactions, their conditions, threshold energy, and cross sections; mechanisms of nuclear fission and fusion and their applications; models of nuclear potentials and their role in theoretical descriptions of nuclear processes[1]

- be able to apply vector and tensor analysis in solving problems in nuclear physics; calculate characteristics of radioactive decays and nuclear reactions (energy, momentum, cross section); interpret experimental data in comparison with theoretical models[2]

- acquire skills in applying acquired knowledge to scientific and applied problems in nuclear and theoretical physics; carrying out analytical and numerical calculations related to nuclear structure and nuclear interactions; using the physico-mathematical framework to model nuclear processes in scientific and practical contexts[3]

  [1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography
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Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

SONA2204	Scattering Theory		
Academic semester	2	ECTS	4

Academic workload			
Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Nishonov Mukhtor

Course content

Scattering theory in classical mechanics. Scattering experiment. Scattering cross section. Reference frames: laboratory and center-of-mass systems. Separation of center-of-mass motion in a two-particle system. Calculation of differential and total scattering cross sections. Scattering theory in quantum mechanics. Schrödinger equation. Integral equation of scattering. Scattering amplitude and differential cross section. Born approximation. Partial wave analysis. Partial amplitudes. Expansion of the integral equation in partial waves. Born approximation for partial waves. Scattering phase shifts. Lippmann–Schwinger equation. Lippmann–Schwinger equation for the T-operator. Methods of solving the Lippmann–Schwinger equation. Representation of the interaction potential in momentum space. Yukawa potential. Scattering S-matrix. Calculation of scattering phases. Bound waves. Blatt–Biedenharn method. Stapp–Ypsilantis–Metropolis method. Effective range expansion.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of scalar and vector fields, their mathematical description and physical interpretation; the main concepts of classical scattering theory: experiment, differential and total cross sections; distinction between laboratory and center-of-mass systems; formulation and physical meaning of the Schrödinger equation in scattering problems; the scattering integral equation and its interpretations; the Born approximation and its applicability; partial wave analysis methods: phase shifts and partial amplitudes; the Lippmann–Schwinger equation and the role of the T-operator; the concept of the S-matrix and its connection with observables; the Yukawa potential and approaches to calculating phase shifts and bound states; the Blatt–Biedenharn, Stapp–Ypsilantis–Metropolis, and effective range methods[1]

- be able to apply vector and tensor analysis to solve scattering problems in classical and quantum mechanics; transition between laboratory and center-of-mass systems; calculate differential and total cross sections in classical problems; formulate and interpret the scattering integral equation and scattering amplitude; use the Born approximation and partial wave methods; solve the Lippmann–Schwinger equation for different potentials; use the S-matrix and phase shifts to analyze scattering processes; apply theoretical physics methods to describe bound states and resonance phenomena; analyze interactions in momentum space[2]

- acquire skills in constructing mathematical models of scattering problems in classical and quantum mechanics; calculating amplitudes and cross sections using analytical and numerical methods; performing partial wave expansions and calculating phase shifts;

applying the Lippmann–Schwinger equation and T-operator for various interactions; analyzing processes using the S-matrix and interpreting its parameters; using the Yukawa and other model potentials in low-energy scattering; applying the effective range method and related approaches to describe physical processes[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. Балашов В.В. Квантовая тероия столкновений. Москва, 2012 . - 289 с.
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Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

KOHN2304	Theory of Condensed States		
Academic semester	3	ECTS	4

Academic workload			
Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Otajonov Sherzod

Course content

Introduction to the theory of condensed states. Distinction from the standard Bardeen–Cooper–Schrieffer (BCS) theory for *s*-wave and unconventional *d*-wave superconductors. Quantum thermalization and localization in many-body systems. Transitions of quantum systems to thermodynamic macrostates and localization mechanisms: ergodic hypothesis (ETH), Anderson localization, many-body localization (MBL). Quantum entanglement and its dynamics. Entanglement entropy and its time evolution after a quench. Tensor network methods. Algorithms such as MPS (Matrix Product States), PEPS (Projected Entangled Pair States), TEBD (Time-Evolving Block Decimation) and their applications to real-time simulations of many-body systems. Floquet engineering and periodically driven systems. Magnus expansion, effective Hamiltonians, Floquet theory, and the concept of time crystals.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of scalar and vector fields, their mathematical description and physical interpretation in the context of quantum physics and condensed matter; the fundamentals of condensed state theory and distinctions between standard and unconventional superconductivity models; the concepts of quantum thermalization and localization (ETH, Anderson localization, MBL); the principles of quantum entanglement and entropy dynamics; the mathematical basis of tensor networks: MPS, PEPS, TEBD; Floquet engineering methods and effective Hamiltonians; and the physical foundations of time crystals[1]

- be able to apply vector and tensor analysis to problems in condensed matter physics; analyze transitions from microscopic to thermodynamic descriptions; describe quantum system behavior under thermalization and localization; interpret entanglement dynamics after quenches; construct and apply tensor network models (MPS, PEPS, TEBD); use Floquet theory and effective Hamiltonians; and formulate physical and mathematical conditions for the emergence of time crystals[2]

- acquire skills in simulating many-body quantum systems using tensor networks; analyzing localization and thermalization in quantum systems; numerically simulating entanglement dynamics with TEBD; developing and analyzing Floquet Hamiltonians for periodically driven systems; studying transitions between ergodic and localized regimes using entropic and spectral characteristics; constructing models of unconventional superconductivity; and applying methods of quantum field theory and quantum information to condensed matter physics[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No   Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography
1. Altland A. & Simons B.— Condensed Matter Field Theory, Cambridge, 2010   2. Chaikin P. M.and Lubensky T. C. Cambridge University Press, New York, 1995.   3. Tinkham M. – *Introduction to Superconductivity*, 2-nashr (2004)   4. Bernevig & Hughes — Topological Insulators and Topological Superconductors (2013)   5. Nielsen & Chuang — Quantum Computation and Quantum Information (2000)   6. Martin R. M. – Electronic Structure (2-nashr, 2020)

Assessments
Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

NOTN2304		Theory of Nonlinear Waves		
Academic semester		3	ECTS	4

Academic workload				
Contact hours		Independent work		
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).		24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)		60 h
Total	36 h	Total		84 h
Total work-load	120 h			

Lecturers

Associate Prof., Dr. Otajonov Sherzod

Course content

Phase space, trajectory, flow. Hamiltonian systems. Liouville's theorem. Continuity equation. Main mechanisms and regularities of nonlinear oscillatory and wave processes. One-dimensional systems. Harmonic oscillator. Classification of singular points. Anharmonic oscillator. Methods for determining singular points of center, saddle type, and analysis of nonlinear oscillators. Duffing equation. Mathematical pendulum. Limit cycle. Self-oscillations. Exactly integrable equations of simple systems. Exact solution of the Duffing equation. Weakly nonlinear systems. Method of direct series expansion. Methods of exact and approximate integration of equations of motion. Phase analysis. Classification of trajectories. Iteration method. Solving nonlinear equations by iteration. Krylov method. Action–angle variables. Spectrum of phase trajectories. Spectrum of nonlinear oscillations. Analysis of nonlinear systems using action–angle variables. Effect of aperiodic external forces on oscillators. Nonlinear resonance. Properties and features of resonance in nonlinear systems. External nonlinear resonance. Fundamental equations of nonlinear wave processes and their applications in physical phenomena. Weak nonlinearity. Origin of nonlinear processes, their nature, and role in understanding physical reality. Korteweg–de Vries (KdV) equation in Lax's interpretation. Connection of the KdV equation with the quantum scattering problem. Inverse scattering method. Method of solving nonlinear dynamical equations. Gelfand–Levitan–Marchenko equation. Scheme for solving the KdV equation. Soliton solutions. Reflectionless potentials. One- and two-soliton solutions of the KdV equation.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of scalar and vector fields, their properties and physical interpretation in the context of phase space; main concepts of phase space (trajectories, flows, oscillations, singular points, limit cycles); Hamiltonian systems, Liouville's theorem, continuity equation; features of nonlinear oscillatory systems (Duffing equation, pendulum, self-oscillations); methods of phase trajectory analysis and classification of singular points (center, saddle, etc.); exact and approximate solution methods of nonlinear equations (Krylov method, series expansions, iterations); action–angle variables, oscillation spectra, and phase trajectory spectra; physical nature of nonlinear resonance; KdV equation, soliton solutions and their interpretation; inverse scattering method and Gelfand–Levitan–Marchenko equation[1]

- be able to apply vector and tensor analysis to model phase dynamics; construct phase portraits and classify singular points; apply analytical and numerical methods (Duffing oscillator, pendulum, etc.); use action–angle variables in oscillation spectrum analysis;

calculate system behavior under nonlinear resonance and external perturbations; apply the inverse scattering method to the KdV equation and derive soliton solutions; interpret the physical meaning of solutions in nonlinear mechanics, acoustics, and optics[2]

- acquire skills in phase analysis of nonlinear oscillators and constructing phase diagrams; analyzing stability near singular points; applying analytical methods (Krylov method, expansions, iterations) for solutions; solving dynamical problems using the Duffing and KdV equations; calculating one- and two-soliton solutions and analyzing their interactions and stability; working with action–angle variables and analyzing spectra; applying the inverse scattering method to wave and soliton processes[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements

Mandatory: No

Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. Бутерин С.А. и Dr. Метод обратной задачи в теории нелинейных волн. Учебное пособие, 2013б СГУ, 115 с.
2. Карлов Н.В., Криченко Н.А.,Колебания, волны, структуры. М. Физматлит, 2003, 496 с.
3. Абдуллаев Ф.Х. Динамический хаос солитонов. Ташкент: Фан, 1990, 168 с.
4. Заславский Г.М., Сагдеев Р.З., Введение в нелинейную физику, М. Наука, 1988.
5. Захаров В.Е., Манаков С.В., Новиков С.П., Питаевский Л.П., теория солитонов. Метод обратной задачи-М: Наука, 1980. 381 с.
6. Лем Дж. Введение в теорию солитонов – М: Мир, 1983, 294 с.

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools

Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

KMNA2304	Quantum Field Theory		

Academic semester	3	ECTS	4

Academic workload			
Contact hours		**Independent work**	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Associate Prof., Dr. Otajonov Sherzod

Course content

Quantum field theory. Action integral. Noether's theorem. Action integral and equations of motion. Noether's theorem and conserved quantities. Scalar field. Action integral for the scalar field. Equations of motion. Real and complex scalar fields. Expansion into positive and negative frequency components. Energy and momentum of the field. Spinor field. Derivation of the Dirac equation. Gamma matrices. Solutions of the free-field equation. Electromagnetic field theory. Lagrangian of the electromagnetic field, constraints, and equations of motion. Polarization decomposition of the field. Interaction Lagrangian. Second quantization. Introduction of interactions. Second quantization illustrated by the harmonic oscillator. Establishing commutation relations. Commutation relations for scalar, spinor, and electromagnetic fields. From basic principles, commutation relations for fermionic and bosonic fields are introduced. Green's functions. Pauli–Jordan D-functions. Green's functions. Wick's theorems. Feynman diagrams. Normal and time ordering. Derivation of the S-matrix via Feynman diagrams. Physical processes. Scattering cross-section. Scattering cross-section of an electron in an external field.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the mathematical description and physical interpretation of scalar and vector fields in quantum field theory; the principle of least action and its relation to equations of motion; Noether's theorem and the connection between symmetries and conservation laws; Lagrangians and equations of motion for scalar, spinor, and electromagnetic fields; the structure and properties of gamma matrices, the Dirac equation, and its solutions; the concept of second quantization and commutation relations for bosonic and fermionic fields; Green's functions and Pauli–Jordan D-functions; rules for constructing Feynman diagrams, time- and normal-ordering, and the structure of the S-matrix; quantum description of interactions and scattering processes[1]

- be able to apply vector and tensor analysis to describe equations of motion and symmetries of Lagrangians; derive Euler–Lagrange equations from the principle of least action; use Noether's theorem to determine conserved currents; perform second quantization of scalar, spinor, and electromagnetic fields with (anti)commutation relations; construct and apply Green's functions and use Wick's theorem; draw and interpret Feynman diagrams for elementary processes; calculate the S-matrix and differential cross-sections of elementary interactions; use the interaction Lagrangian to describe quantum processes[2]

- acquire skills in mathematical formalization of field equations and their quantization;

working with Lagrangians of different types of fields and deriving Euler–Lagrange equations; implementing second quantization with (anti)commutation relations; constructing and analyzing Feynman diagrams for interaction processes; calculating physical quantities (energy, momentum, Noether currents) in quantum field theory; applying Green's functions and operator methods to physical processes; modeling scattering processes and computing interaction probabilities via the S-matrix[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements

Mandatory: No

Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. С.Вайнберг. Квантовая теория полей, 3-томник, М., 2002.
2. М.М.Мусаханов, В.А.Паздзерский, Б.А.Файзуллаев. Релятивистик квант механикаси. Т., "Университет", 2003 й.
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5. Райдер. Квантовая теория поля. М., Мир, 1987.
6. H. Kleinert. Particles and quantum fields, 1996.
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Assessments

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Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools

Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

STFI2304		Statistical Physics		
Academic semester		3	ECTS	4

Academic workload				
Contact hours		**Independent work**		
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).		24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)		60 h
Total	36 h	Total		84 h
Total work-load	120 h			

Lecturers

Associate Prof., Dr. Fayzullayev Biruni

Course content

Landau Fermi-liquid theory. Physical foundations of Landau's Fermi-liquid theory. Introduction of the quasiparticle concept. Representation of quasiparticles as an ideal gas at low temperatures. Quasiparticle collision function. Zero-sound propagation in a Fermi liquid. Distribution function for quasiparticles in a Fermi liquid and the corresponding kinetic equation. Three conditions corresponding to sound waves for this distribution function. Zero-sound propagation. Quasiparticles in Bose liquids. Quasiparticles in Bose liquids: acoustic phonons and rotons. Landau's theory of superfluidity. Landau's two-fluid model of superfluid helium. Theory of the non-ideal Bose gas. Criterion of non-ideality of a gas—s-wave scattering theory. Bogoliubov's criterion for Bose–Einstein condensation. Canonical transformations of the Hamiltonian and diagonalization. Emergence of an ideal gas of quasiparticles. Appearance of condensed and non-condensed real particles as a result of canonical transformation of the Hamiltonian. Microscopic theory of superconductivity by Bardeen–Cooper–Schrieffer (BCS). Formulation of the BCS theory in the Bogoliubov representation. Fermion Hamiltonian. Introduction of Bogoliubov canonical transformations. Diagonalization of the Hamiltonian. Derivation of the energy gap equation. Quasiparticle dispersion. Coherence length and its physical meaning. Derivation of three conditions for the formation of Cooper pairs.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the mathematical description and physical interpretation of scalar and vector fields in statistical physics; the fundamentals of Landau Fermi-liquid theory and the quasiparticle concept; properties of quasiparticles in Fermi and Bose liquids and their role in describing collective excitations; the kinetic equation for Fermi liquids and conditions for zero-sound propagation; the nature of phonons and rotons in Bose liquids; the structure of Landau's two-fluid model; criteria of Bose–Einstein condensation, properties of the non-ideal Bose gas, the role of s-wave scattering and Bogoliubov's method; physical meaning of canonical transformations of the Hamiltonian; structure and postulates of BCS theory, fermion Hamiltonian, and origin of the energy gap; role of Cooper pairs, quasiparticle dispersion, and coherence length[1]

- be able to apply vector and tensor analysis to describe statistical systems; analyze quasiparticle behavior in Fermi and Bose media and formulate equations of motion; use kinetic equations and collision functions to model collective excitations; apply Landau's model to superfluidity and interpret two-fluid parameters; use perturbation theory methods and canonical transformations to diagonalize Hamiltonians; derive the gap

equation and analyze dispersion relations in BCS theory; model the formation of Cooper pairs and compute coherence length[2]

- acquire skills in working with quasiparticle Hamiltonians and applying canonical transformations in statistical physics problems; computing and analyzing excitation spectra in Fermi and Bose media; using kinetic and hydrodynamic methods to describe collective phenomena; applying Landau's model to superfluid systems, including liquid helium; deriving and applying equations of the microscopic BCS theory of superconductivity; quantitatively describing Bose–Einstein condensation and the formation of the superconducting state[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods

Lectures; Problem solving; Self-study; Group work

Admission requirements

Mandatory: No

Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. Л.Д. Ландау, Е.М. Лифшиц, Механика, 1990
2. Л.Д. Ландау, Е.М. Лифшиц, Нерелятивистская квантовая механика 1990.
3. Л.Д. Ландау, Е.М. Лифшиц, Статистическая физика том 5 , часть 1, 1989.
4. Л.Д. Ландау, Е.М. Лифшиц, Статистическая физика том 9 , часть 2, 1989.

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools

Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

GRNA2304		Theory of Gravitation		
Academic semester		3	ECTS	4

Academic workload				
Contact hours		Independent work		
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).		24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)		60 h
Total	36 h	Total		84 h
Total work-load	120 h			

Lecturers

Prof., Dr. Akhmedov Bobomurod

Course content

Tensor analysis in curved spaces. Field equations. Central field. Equality of inertial and gravitational mass. Principle of equivalence. Principle of general covariance. Definitions of vectors and tensors in curved space. Covariant and contravariant tensors. Metric tensor. Christoffel symbols. Covariant derivative. Geodesics. Parallel transport. Curvature tensor (Riemann–Christoffel tensor). Ricci tensor. Bianchi identities. Geodesic deviation. Lie derivative. Killing vector. Energy–momentum tensor. Gravitational field equations. Cosmological constant. Schwarzschild solution. Motion in a central field. Gravitational collapse of a spherical body. Chandrasekhar limit. Linearized field. Plane waves. Gravitational wave radiation. Big Bang. Friedmann–Robertson–Walker metric. Solutions of the Friedmann equations. Hubble constant. Cosmological models.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of mathematical definitions and physical interpretation of scalar and vector fields in curved spacetime; distinction between covariant and contravariant objects; properties of the metric tensor, Christoffel symbols, and covariant derivatives; physical meaning of geodesics, parallel transport, Riemann curvature tensor, Ricci tensor, and Bianchi identities; principles of general covariance and equivalence, and their role in formulating general relativity; Einstein's field equations and the structure of the energy–momentum tensor; Schwarzschild solution and its applications; the nature of gravitational collapse, the Chandrasekhar limit, and conditions for black hole formation; properties of gravitational waves in the linear approximation; basics of relativistic cosmology: Friedmann–Robertson–Walker metric, Friedmann equations, cosmological constant, and Hubble constant[1]

- be able to apply vector and tensor analysis to problems of gravitation in curved spaces; compute geodesics, curvature tensors, and Lie derivatives for a given metric; analyze the energy–momentum tensor and use it in gravitational field equations; interpret solutions of Einstein's equations, including Schwarzschild and Friedmann metrics; apply equations of motion to describe trajectories of bodies in gravitational fields; use linear approximation methods to describe gravitational waves; analyze cosmological models and compute parameters of the expanding Universe[2]

- acquire skills in working with tensor equations in curvilinear coordinates and metric spaces; practical use of Christoffel symbols, curvature tensors, and geodesic equations in gravitational problems; calculation of parameters and characteristics of cosmological models based on the Friedmann equations; analysis of gravitational collapse, gravitational

radiation, and motion of particles in curved space; physical interpretation of Einstein's equations for different metrics; integration of general relativity principles into the study of physical and astrophysical processes[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. Л.Д.Ландау, Е.М.Лифшиц, Теория поля. М., Наука, 1988.
2. Ч.Мизнер, К.Торн, Дж.Уилер. Гравитация. М., Мир, 1977. (1,2,3 - том)
3. Б.А.Файзуллаев. Умумий нисбийлик назарияси. Т., Университет, 2010.
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5. Hartle J.B., Gravity. An Introduction to Einstein's General Relativity, University of California, Santa Barbara, 2008.
6. Rezzolla L, Zanotti O, Relativistic Hydrodynamics, Oxford University Press, 2013.
7. C. Bambi, Umumiy nisbiylik nazariyasiga kirish. «Renessans press», Toshkent-2025

Assessments

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Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

RAKO2304	Relativistic Astrophysics and Cosmology		

Academic semester	3	ECTS	4

Academic workload

Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Prof., Dr. Akhmedov Bobomurod

Course content

Subject and scope of the special course "Relativistic Astrophysics." Equality of inertial and gravitational mass. Principle of equivalence. Principle of general covariance. Behavior of vectors and tensors in curved space. Covariant and contravariant tensors. Covariant derivative. Geodesic and parallel transport. Connection between metric tensor and Christoffel symbols. Riemann–Christoffel curvature tensor. Ricci tensor. Bianchi identities. Geodesic deviation. Lie derivative. Condition for the existence of a Killing vector. Gravitational field equations. Schwarzschild solution. Motion in a central gravitational field. Gravitational collapse of a spherical body. Chandrasekhar limit. Tolman–Oppenheimer–Volkoff equation. Gravitational field of rotating bodies. Kerr black hole, neutron stars, and white dwarfs. Energy characteristics of black holes and magnetized neutron stars. Contemporary problems of relativistic astrophysics. Modern astrophysical observations using space telescopes.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of scalar and vector fields in the context of general relativity, their mathematical description and physical interpretation; behavior of vectors and tensors in curved space, distinction between covariant and contravariant tensors; properties and role of the metric tensor, Christoffel symbols, and covariant derivatives in describing gravitation; geometric meaning of geodesics, parallel transport, Riemann tensor, Ricci tensor, and Bianchi identities; principles of general covariance and equivalence, equality of inertial and gravitational mass; Einstein's field equations and their physical meaning; analytical solutions of Einstein's equations, including Schwarzschild and Kerr metrics, and their physical implications; physical characteristics of compact astrophysical objects (white dwarfs, neutron stars, black holes); Tolman–Oppenheimer–Volkoff equation for describing stellar equilibrium; energy characteristics of relativistic objects and observational confirmations of general relativity[1]

- be able to apply tensor analysis and elements of differential geometry to describe gravitational fields in astrophysics; use Einstein's equations to analyze particle and light motion in curved spacetime; compute geodesics, curvature tensors, and other geometric characteristics of given metrics; analyze physical parameters of models of gravitational collapse, black holes, neutron stars, and white dwarfs; interpret Schwarzschild and Kerr solutions in real astrophysical contexts; apply stability criteria and limiting masses (e.g., Chandrasekhar limit) in stellar modeling; use observational astrophysics data, including results of space missions, to verify relativistic models[2]

- acquire skills in analyzing and interpreting tensor equations in relativistic astrophysics problems; constructing models of gravitational fields for different matter configurations;

solving equations of motion in given gravitational backgrounds (central fields, rotating bodies); applying the Tolman–Oppenheimer–Volkoff equation to describe stellar structure; estimating energy characteristics of compact objects; comparing theoretical models with astronomical observations; working with scientific literature and space-based observational data in the field of relativistic astrophysics[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography

1. Hartle J.B., Gravity. An Introduction to Einstein's General Relativity, University of California, Santa Barbara, 2008.
2. Rezzolla L, Zanotti O, Relativistic Hydrodynamics, Oxford University Press, 2013.
3. Ч. Мизнер, К. Торн, Дж. Уилер, Гравитация, в 3-х тт., М.: «Мир», 1977г.
4. Ч. Мизнер, К. Торн, Дж. Уилер, Гравитация, в 3-х тт., М.: «Мир», 1977г.
5. С. Вейнберг, Гравитация и космология, М.: «Мир», 1975 г.
6. Л.Д. Ландау, Е.М. Лифшиц, Теория поля, М.: «Наука», 1973 г. (и другие издания).
7. И. Шапиро, С.А. Тьюколски, Черные дыры, белые карлики, и нейтронные звезды, в 2 частях, М.: «Мир», 1985 г.
8. C. Bambi, Umumiy nisbiylik nazariyasiga kirish. «Renessans press», Toshkent-2025

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

STMO2304	Standard Model		
Academic semester	3	ECTS	4

Academic workload			
Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Prof., Dr. Musakhanov Mirzayusuf

Course content

Fundamental interactions. Classification of elementary particles: leptons and quarks. Gauge symmetry groups. Historical development of the Standard Model. Principles of invariance and conservation laws. Gauge symmetry. Fermions and bosons. Particles and antiparticles. Strong, weak, and electromagnetic interactions of particles. Invariance and operators in quantum mechanics. Quantum chromodynamics (QCD). Quarks and leptons. Weak interactions for quarks and leptons. Phenomenological Fermi Lagrangian for weak interactions. Quark model of hadrons. Yang–Mills theory. Unification of electromagnetic and weak interactions. Gauge group SU(2)×U(1). Spontaneous symmetry breaking. Goldstone theorem. Goldstone bosons for complex scalar fields. Higgs–Kibble mechanism. Vacuum expectation value. Higgs boson. Origin of particle masses. Quantum flavor dynamics. Quark masses. Cabibbo matrix. Quark mixing. CP violation. Cabibbo–Kobayashi–Maskawa matrix. Functional integration formalism. Quantization via path integral: scalar, spinor, and gauge fields. Generating functional for scalar fields. Functional integration. Green's functions for free particles. Generating functional for interacting fields. ϕ^4 theory. Analysis of Faddeev–Popov unitarity in two dimensions.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the physical nature and role of scalar and vector fields in gauge theories and particle physics; main types of elementary particles (leptons, quarks, fermions, bosons), their classification and properties; fundamental interactions (strong, weak, electromagnetic), their mediators and properties; principles of symmetry, gauge invariance, conservation laws, and corresponding symmetry groups (SU(3), SU(2)×U(1)); structure of the Standard Model and mechanisms of spontaneous symmetry breaking; essence and consequences of the Higgs mechanism, role of the Higgs boson in generating particle masses; basics of QCD (the theory of strong interactions of quarks and gluons); features of weak interactions — Fermi Lagrangian, quark mixing, Cabibbo and Cabibbo–Kobayashi–Maskawa matrices; foundations of functional integration, construction of Green's functions, quantization of scalar, spinor, and gauge fields; content of the Goldstone theorem and quantum description of Goldstone bosons[1]

- be able to apply tensor and group analysis to describe gauge symmetries in physical theories; use gauge Lagrangians to describe electroweak and strong interactions; formalize weak interactions using the Fermi Lagrangian and mixing matrices; analyze effects of symmetry breaking, including CP violation, within the Standard Model; apply the Higgs mechanism to explain mass generation in bosons and fermions; use methods of quantum field theory and functional integration to calculate process amplitudes; compute

Green's functions for free and interacting fields; analyze physical implications of the ϕ^4 Lagrangian and equations of motion for quantized fields; formulate and verify the correctness of gauge fixing using the Faddeev–Popov method[2]

- acquire skills in analyzing symmetries of physical systems using group theory and Lagrangian invariants; constructing gauge models of interactions and corresponding Lagrangians; applying the concepts of fermionic and bosonic fields to model elementary interactions; using functional integration in quantum field theory problems; interpreting and computing quantum effects in symmetry-breaking theories; diagonalizing Lagrangians and mixing matrices in particle physics problems; comparing predictions of the Standard Model with modern experimental results[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography
1. Modern Elementary Particle Physics: Explaining and Extending the Standard Model , Gordon Kane, Cambridge University Press, 2017 2. Particles, Fields and Forces: A Conceptual Guide to Quantum Field Theory and the Standard Model, Wouter Schmitz, Springer, 2019 3. Mathematical Gauge Theory: With Applications to the Standard Model of Particle Physics, Mark J.D. Hamilton, Springer, 2018

Assessments

Assessment of students' knowledge is carried out in accordance with the Regulation on the system for monitoring and assessing students' knowledge in higher education institutions developed based on the credit-module system.

Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

Final Assessment: conducted based on versions covering all completed topics. Each student receives a set consisting of 2 theoretical questions and 1 problem on topics studied during the semester. Answers are submitted in written form. After submitting the written work, the student answers follow-up questions orally and can earn up to 5 points for each answer. The Final Assessment grade is calculated as the arithmetic average.

Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

KVEL2304		Topics in Quantum Electrodynamics		
Academic semester		3	ECTS	4

Academic workload

Contact hours		Independent work	
Lectures	18 h	Preparation for classroom sessions (preparation for practical and laboratory classes, preparation of reports, and submission of laboratory work).	24 h
Problem solving	18 h	Literature study (preparation of essays, exploration of additional topics)	60 h
Total	36 h	Total	84 h
Total work-load	120 h		

Lecturers

Prof., Dr. Musakhanov Mirzayusuf

Course content

Dirac equation and its nonrelativistic limit. Algebra of Dirac matrices. Quantization of fermions using the path integral method and general formula for the S-matrix in QED. Feynman rules for QED. Furry's theorem. Ward–Takahashi identities. Basic amplitudes in QED. Divergence index of diagrams and renormalization conditions in QED. Electron and photon propagators. Mass operator. Polarization operator. Radiative corrections to Coulomb's law. Vertex operator and anomalous magnetic moment of the electron. Electron form factors. Calculation of form factors. Analytic properties of form factors. Anomalous magnetic moment of the electron.

Learning objectives

Upon successful completion of this course, students should:

- possess knowledge of the physical role of scalar and vector fields in constructing QED Lagrangians; Dirac equation, its physical meaning, gamma matrix structure, and nonrelativistic limit; principles of fermion field quantization via functional integration and the S-matrix formalism in QED; Feynman rules for calculating interaction amplitudes; content of Furry's theorem and Ward–Takahashi identities, their role in renormalization; concept of divergence index of diagrams and renormalizability conditions of the theory; structure of electron and photon propagators, mass and polarization operators; physical nature of radiative corrections, including modifications of Coulomb's law; structure of the vertex operator and significance of the electron anomalous magnetic moment; definition and analytic properties of electron form factors in QED[1]

- be able to apply vector and tensor analysis to work with quantum field Lagrangians; use gamma matrices and Clifford algebra in constructing and analyzing the Dirac equation; apply functional integration for fermion field quantization and derivation of expressions for the S-matrix; construct and interpret Feynman diagrams, determine divergence indices and renormalizability conditions; compute amplitudes of elementary processes in QED; use Ward–Takahashi identities in analyzing symmetries and renormalization; calculate radiative corrections to electromagnetic interactions; analyze the structure and behavior of vertex form factors[2]

- acquire skills in practical work with fermion and boson fields, including the procedure of second quantization; performing calculations of process amplitudes and propagators using Feynman rules; applying mass and polarization operator concepts to analyze quantum corrections; computing and interpreting radiative effects, including the anomalous magnetic moment; constructing diagrammatic representations in QED problems; analyzing form factors and using their analytic properties to interpret observable

phenomena[3]

[1] knowledge; [2] skills; [3] abilities;

Teaching and learning methods
Lectures; Problem solving; Self-study; Group work

Admission requirements
Mandatory: No
Recommended: Knowledge of high school physics, mathematical analysis, and geometry

Bibliography
1. Modern Elementary Particle Physics: Explaining and Extending the Standard Model , Gordon Kane, Cambridge University Press, 2017
2. Particles, Fields and Forces: A Conceptual Guide to Quantum Field Theory and the Standard Model, Wouter Schmitz, Springer, 2019
3. Mathematical Gauge Theory: With Applications to the Standard Model of Particle Physics, Mark J.D. Hamilton, Springer, 2018

Assessments

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Type of Assessment	CA	FA
Timing	27-28 th week	36-37 th week
Form of Assessment	oral	written and oral exam

Continuous Assessment assessment: conducted after the completion of sections related to lectures and problem-solving, covering approximately half of the course. The material will be distributed into versions containing 2 theoretical questions and 1 problem. Answers are submitted in written form. Each correct answer is graded up to 5 points.

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Educational Materials and Media Tools
Projector; white/black board; printed handouts; visual aids for presentations; demonstration equipment and materials

Scietific Activity			
Academic semester	1-4	ECTS	60
Academic workload			
Independent work			
Scientific and Pedagogical Activity			180h
Research Internship			240 h
Scientific Research and Preparation of the Master's Thesis			1050 h
Final State Attestation: Defense of the Master's Thesis			150 h
Total work-load			**1620 h**
Lecturers			
Academic supervisors			

COURSE CONTENT

I. SCIENTIFIC AND PEDAGOGICAL ACTIVITY
1.1. The Content of Scientific and Pedagogical Activity

Scientific and pedagogical work is carried out at higher education institutions, as well as at institutions of professional development and retraining. It may also be conducted at secondary specialized or vocational education institutions corresponding to the trainee's field of specialization. Moreover, scientific and pedagogical work may be conducted at foreign higher education institutions on the basis of bilateral or other agreements.

Scientific and pedagogical work includes:

- developing pedagogical skills and competencies through the use of modern pedagogical and information technologies, as well as interactive teaching and learning methods;
- organizing the scientific and methodological support of the educational process and ensuring the formation of the necessary knowledge and skills.

Scientific and pedagogical activity constitutes an important component of the master's program. It enables undergraduates to apply the acquired scientific and theoretical knowledge in practice, organize classroom sessions based on innovative pedagogical and information-communication technologies, master international standards and advanced foreign experience in assessing students' knowledge, become familiar with activities aimed at ensuring the quality of education at higher education institutions, and define the objectives of their own scientific and pedagogical work.

1.2. Tasks Performed by the Master's Student During Scientific and Pedagogical Activity

During the implementation of scientific and pedagogical work, the master's student must cooperate closely with the academic supervisor in order to acquire scientific and pedagogical proficiency. The master's student should have an initial understanding of their field of specialization, develop professional skills in accordance with new requirements for the chosen specialty, and understand how the education system and process are organized and conducted. The purpose of familiarizing the master's student with modern scientific and pedagogical standards is to prepare them, as future specialists, to provide students with practical knowledge in their area of specialization.

Scientific and pedagogical work includes:

- participation in and conducting various types of classes in specialized disciplines, such as lectures, laboratory sessions, seminars, practical and other types of training;
- preparation of lecture materials and lesson plans;
- studying and applying new pedagogical and information technologies;
- using the credit-module system for assessing students' knowledge;
- learning how to organize and provide methodological support for students' independent work;
- developing methodological guidelines;
- conducting educational and upbringing (character-building) activities.

As a result of scientific and pedagogical activity, the master's student should:
- acquire practical knowledge of innovative pedagogical and information-communication technologies, methods for enhancing the educational process, and international standards and advanced techniques for assessing students' knowledge, skills, abilities, and competencies;
- master the organizational and methodological support of independent learning and the use of distance learning technologies;
- be able to develop educational and regulatory documents (qualification requirements, curriculum, working curriculum, course syllabus, working course syllabus, educational-methodological complex, and calendar plan), as well as create and use educational materials (textbooks, teaching manuals, methodological instructions);
- conduct traditional and non-traditional (innovative) forms of academic classes (lectures, practicals, laboratories, seminars, etc.) at higher education institutions, and prepare lecture materials and teaching plans (technological maps);
- develop organizational and methodological support for monitoring students' knowledge, skills, abilities, and competencies;
- gain experience in organizing and providing methodological support for spiritual, educational, and upbringing activities at higher education institutions;
- attend classes conducted by leading professors and lecturers of the department (as determined by the department and academic supervisor);
- conduct academic sessions for student groups under the supervision of the academic advisor or leading professors;
- participate in the development of pedagogical technologies and preparation of educational-methodological complexes for specific academic subjects;
- carry out educational, independent, and upbringing activities with undergraduate students;
- acquire theoretical knowledge aimed at improving pedagogical skills;
- develop interest in the teaching profession, learn the key scientific concepts of pedagogy, and gain skills in forming pedagogical research ideas;
- enhance qualifications in conducting various types of classes in specialized disciplines;
- study and apply new pedagogical and information technologies, and prepare lecture materials and teaching plans based on them;
- learn to organize and provide methodological support for students' independent study, and develop methodological guidelines for self-learning;
- study and organize educational and upbringing activities;
- master the methods of preparing methodological manuals for lectures and practical classes, as well as compiling working programs and calendar plans.

The types of activities carried out by the master's student at the department — including lectures, practical sessions, events, and independent work — as well as the academic subjects and topics involved, are determined by a working group consisting of the head of the department, the academic supervisor, and scientific advisors.

Each month, the master's student submits a progress report at the department meeting in accordance with the approved plan. Based on the report, the department meeting issues a decision stating that the plan has been either "completed" or "not completed."

At the end of the semester, based on the monthly reports, the master's student prepares a final report on scientific and pedagogical activity for the semester. A working group consisting of the head of the department, the supervisor of scientific and pedagogical work, and scientific advisors reviews the report and, taking into account the department's decision and the supervisor's recommendation, records the master's student's final grade in the logbook of scientific and pedagogical work.

II. RESEARCH WORK AND PREPARATION OF THE MASTER'S DISSERTATION

The main purpose of research work is the preparation of the master's dissertation. It is aimed at addressing priority and urgent issues in the fields of science and education, technology, and economics by finding scientifically grounded solutions to specific problems, developing recommendations, and

analyzing results using mathematical, statistical, and other methods.

The master's dissertation represents the final outcome of research work carried out on the basis of the theoretical and practical knowledge acquired by the student during the learning process and completion of the master's program.

Research work is conducted in the scientific research laboratories of higher education institutions, in academic and sectoral research institutes, and in the research divisions of enterprises and organizations.

It is permitted to conduct research work at educational institutions, scientific centers, enterprises, and organizations of foreign countries under bilateral or other agreements.

The scope, organizational, and methodological support of research work are defined in the program developed by the department responsible for training specialists, taking into account the requirements of employers.

Research work includes:

➢ studying standard models of objects and processes within the master's specialty and learning research methodologies;

➢ studying and describing experimental setups, modern instruments, and other equipment used in experimental research;

➢ conducting scientific research using modern information technology tools;

➢ processing, analyzing, and presenting experimental results, drawing conclusions, preparing scientific papers, and developing recommendations;

➢ developing practical skills in independent research activity;

➢ using up-to-date databases based on the latest achievements in science, technology, and engineering, and applying them in the preparation of the master's dissertation.

Each student is offered a list of topics based on the database created by the department for their specialty. Accordingly, each student, in consultation with their academic supervisor and on the recommendation of the department, selects a dissertation topic from the department's topic database.

The topics of master's dissertations are developed by the teaching staff of university departments, as well as by researchers from the scientific institutions of the Academy of Sciences of the Republic of Uzbekistan, sectoral research, and design institutes.

As a rule, dissertation topics are devoted to addressing relevant scientific research problems or solving specific practical tasks.

Each master's student independently selects a dissertation topic from the recommended topic database for their field of study. Topic selection is considered one of the most responsible stages of preparation, during which the student receives advice from leading professors and lecturers of the department.

A properly chosen dissertation topic ensures the successful completion of the work.

An academic supervisor is assigned to the master's student during the topic selection process.

Supervision of the master's dissertation is carried out by professors, doctors of science, associate professors, candidates of science working at higher education institutions, researchers from scientific institutions of the Academy of Sciences of the Republic of Uzbekistan, as well as highly qualified and experienced specialists from organizations, and foreign experts who hold master's, scientific, or academic degrees in accordance with the established procedure.

If the appointed academic supervisor does not work at the higher education institution where the student is studying, an additional academic advisor from among the department's teaching staff is assigned to the student.

In accordance with the established requirements, both the academic supervisor and the academic advisor share equal responsibility for the completion of the master's dissertation.

The academic supervisor's responsibilities include:

➢ preparing a schedule of consultations in order to provide systematic assistance on issues that may arise during the research process;

➢ participating in the selection of research methods and assisting the student in applying them in

their research work;

➢ monitoring the implementation of tasks in accordance with the approved calendar plan and ensuring that the master's dissertation is completed on time;

➢ providing an official evaluation of the master's dissertation prior to the preliminary defense.

Organization of Research Work and Preparation of the Master's Dissertation
Stage I (1st semester)

At the first stage of research work and preparation of the master's dissertation, the student selects the topic of the dissertation from the list of approved subjects, substantiates the relevance of the chosen topic, defines the aim and objectives of the study, as well as its object and subject. The student analyzes foreign and national scientific and methodological literature in order to determine the level of study of the topic and collects the necessary data. Based on the accumulated materials, the master's student develops a preliminary plan of the dissertation. During the course of research, the plan may be revised and amended as needed.

The results of the student's research work at Stage I are discussed monthly at the department meetings throughout the first semester. At the end of the semester, each student presents a report on the results of Stage I, which is reviewed and attested by the department according to its decision.

During Stage I, the student is advised to focus on the following: conducting research, identifying scientific problems and exploring general methods and approaches to their solution; processing and generalizing information obtained during research; substantiating the relevance of the topic; developing scientific-theoretical, methodological, and psychological-pedagogical principles; reviewing and identifying the most effective methods for solving the research problem.

During the 1st semester, master's students are expected to: select the dissertation topic; determine their scientific supervisor; define the purpose and objectives of their research; jointly with the supervisor, develop a plan for the master's dissertation; identify the research object and subject; collect relevant materials from libraries and online sources; and prepare a written report on the work performed.

Expected outcomes of research work during the 1st semester:

➢ preparation and approval of an individual work plan reflecting the student's research activities;

➢ clarification and approval of the dissertation topic, objectives, and tasks, as well as identification of the research object and subject;

➢ selection and approval of the direction of research activity (master's dissertation), substantiation of its relevance, study of the level of scientific development of the problem, and preparation of analytical literature reviews on the research topic;

➢ participation in scientific seminars.

Stage II (2nd semester)

The main outcome of the student's scientific activity is the master's dissertation, which must fully comply with all requirements established by the relevant regulations.

The results of the student's research during the 2nd semester are discussed monthly at the department meetings. At the end of the semester, each master's student presents a report on the progress of research and completed work, which is reviewed and attested by the department.

During the 2nd semester, the master's student works on the theoretical part of the dissertation, analyzes relevant literature, normative documents, scientific papers, and statistical data, formulates their own approach to the scientific ideas and concepts found therein, and develops the program and methodology of experimental work. The student describes didactic materials, algorithms, methods, software tools, instruments, and visual materials used in experimental studies. Methods used for processing and generalizing experimental and statistical data are also explained. With the assistance of the scientific supervisor, the student prepares a scientific article or conference abstract based on the dissertation topic. The student also prepares annotations (summaries) of the analyzed sources—monographs, dissertations, textbooks, or methodological manuals—describing their content, relevance

to the research problem, strengths, and weaknesses.

Expected outcomes of research work during the 2nd semester:

➢ preparation of a detailed outline (content) and the first chapter of the master's dissertation;
➢ development of a schedule for dissertation preparation;
➢ selection and study of the main bibliographic sources forming the theoretical basis of the research;
➢ participation in scientific seminars;
➢ conducting analytical research in the chosen field of study;
➢ preparation and defense of a review paper on the research topic;
➢ preparation and publication of scientific articles or abstracts for presentation at scientific-practical and inter-university conferences.

Stage III (3rd semester)

At the third stage of research work, the master's student completes the dissertation section devoted to the analysis and discussion of the obtained results, interprets the research process, and proposes experimental setups and technological schemes where appropriate.

At this stage, the student finalizes and formats the dissertation in accordance with the established requirements.

Expected outcomes of research work during the 3rd semester:

➢ Submission of the preliminary version of the master's dissertation to the scientific supervisor;
➢ Preparation of the final version of the dissertation.

During Stage III, the student revises the dissertation based on the results obtained, practical experience gained, and supervisor's feedback.

The progress of the student's work is discussed monthly at department meetings. At the end of the semester, each master's student presents a report on the results of Stage III in the presence of their scientific supervisor and the head of the department; the student's work is evaluated and attested by the department.

III. SCIENTIFIC SEMINAR
Content of the Scientific Seminar

Purpose of the scientific seminar: the main purpose of the scientific seminar is to develop research competencies and practical skills among master's students in the process of preparing course papers and master's dissertations.

Main objectives of the scientific seminar:

➢ To teach master's students the methodology of scientific research, methods of analyzing and reviewing scientific literature, as well as techniques and tools for collecting, processing, and professionally presenting specialized information;
➢ To develop students' skills in conducting scientific discussions, formulating scientific arguments, and presenting and defending the results of their research (master's dissertations) before an audience;
➢ To assist students in developing and refining their research plans;
➢ To assess the competencies, knowledge, and skills related to the formation of a professional worldview;
➢ To provide professional orientation for master's students, helping them to select research directions and dissertation topics;
➢ To form academic skills necessary for conducting research, preparing and writing scientific papers;
➢ To discuss students' research projects and completed studies.

The ultimate goal of the scientific seminar is to make research activity an integral and systematic component of the educational process, to involve students in the life of the scientific community, and to facilitate their mastery of the methodology, technology, and tools of scientific research.

Organization of the Scientific Seminar

Attendance at scientific seminars is mandatory for all master's students. The scientific seminar, as a form of organizing students' research activities, continues throughout the entire educational process.

Scientific seminar activities are carried out in the following forms:

- conducting lectures and consultation sessions by leading scholars on the theory, methodology, and current issues of the respective field or discipline;
- organizing presentations and master classes by leading scientists and practitioners to identify and define relevant analytical and research tasks;
- holding discussions on materials from national and international scientific publications concerning modern problems in relevant scientific and economic fields;
- organizing business games and debates on pressing issues within the respective disciplines and master's programs, led by university professors and invited researchers or practitioners;
- conducting training sessions on the preparation of informational and analytical materials;
- organizing presentations by students on the results of their research (master's dissertations);
- discussing scientific articles and monographs;
- holding discussions of students' prepared articles and theses;
- conducting the defense of course papers (projects);
- conducting preliminary defenses of master's dissertations.

The scientific seminar is essentially focused on the preparation of the master's dissertation. Preparing the master's dissertation is the main direction of activity for participants of the scientific seminar.

In the first semester:

Introductory and professionally oriented lectures are organized by leading professors and experts in the relevant field of the master's program. They share their research experience, familiarize master's students with the procedures for organizing research projects, defining research objectives, and understanding the structure and requirements of scientific work.

During this process, special attention is given to identifying key research areas within the scope of the master's program, enabling students to select dissertation topics and outline initial research plans.

It is recommended that during the **first semester** students:

- become familiar with the procedures for organizing and conducting the scientific seminar;
- receive information about the department's scientific and innovative activities and research directions;
- attend orientation lectures by leading professors and experts on the priority areas and issues of the master's program;
- participate in lectures by researchers working in the relevant field of the master's program;
- take part in discussions of master's dissertation topics, defining their goals, tasks, and expected results;
- present and discuss their chosen dissertation topic, object and subject of research, goals, tasks, expected results, and scientific novelty.

In the **second semester**:

Alongside conducting research and writing the theoretical chapters of the master's dissertation, students prepare a course paper related to their dissertation topic. The course paper, as well as articles and theses written on the selected dissertation topic, serve as intermediate forms of the dissertation preparation process. Writing the course paper is an important stage and an integral part of preparing the master's dissertation.

Course paper topics are connected with the search for scientific and practical ideas within the

master's program and the development of methodological and instrumental approaches to their implementation.

Students must prepare course papers and presentations and discuss them at the scientific seminar. At this stage, each student should clearly define the topic and structure of the course paper in accordance with the chosen dissertation subject.

During the seminar, the following activities take place:

- presentation and discussion of analytical reviews (first chapter or its sections) related to the dissertation topic, including main conclusions, possible adjustments to research goals and objectives, and the bibliography;
- discussion of the first (or second) chapter of the master's dissertation;
- discussion of students' scientific articles and theses;
- defense of course papers.

In the second academic year: ehe organization of the scientific seminar is primarily focused on the process of writing the master's dissertation.

In the **third semester**, master's students present the results of their research — completed chapters and sections of their dissertation — at the scientific seminar. Scientific articles and theses prepared by students are also discussed.

In the **fourth semester**, during the research internship, master's students carry out research based on modern technologies and innovations in relevant sectors of the economy. They collect materials for the preparation of their master's dissertation (or part of it), conduct necessary experimental and test work, and present the results — including completed chapters and sections of the dissertation — during the seminar.

At the end of the second academic year, the **preliminary defense of the master's dissertation** is held.

The preliminary defense is an open seminar attended by the scientific supervisor and other interested participants, during which the dissertation is presented and discussed.

The master's student finalizes the dissertation, prepares a presentation for the preliminary defense, and based on the results of the discussion, receives recommendations for final revision and improvement of the dissertation in accordance with the comments and suggestions made.

Management of the Scientific Seminar

The head of the scientific seminar is appointed by the department from among its leading professors and instructors. Given that the scientific seminar serves as a means of monitoring the progress of master's students' research work and the activities of scientific supervisors during the preparation of master's dissertations, it is advisable that this responsibility be assigned to the Head of the Department.

The seminar head carries out the overall coordination of the department's activities in organizing and conducting the scientific seminar.

They organize and manage the seminar's work involving the department's leading professors and instructors (scientific supervisors) as well as master's students.

The head of the scientific seminar: develops the program of the scientific seminar; forms the list of invited professors, instructors, and practitioners; assigns the final grade for each master's student's performance and participation in the seminar.

Overall responsibility for the organization and conduct of the scientific seminar lies with the Head of the Department.

The scientific seminar may be conducted in an open, discussion-based format with the participation of master's students enrolled in the respective program, researchers, instructors, staff members of the university's scientific divisions, as well as invited employers, experts, and leading specialists.

Evaluation of Master's Students' Performance in the Scientific Seminar

A master's student's grade for the scientific seminar is determined based on the following criteria:

- the student's level of activity and engagement in seminar discussions;
- the degree of completion and timely presentation of the corresponding chapters of the master's dissertation (according to the planned research schedule);
- the presence, quality, and defense level of the course paper and its presentation;
- the availability of publications (articles or theses) related to the topic of the master's dissertation;
- participation in conferences, round-table discussions, and other academic events.

IV. SCIENTIFIC INTERNSHIP

The scientific internship is one of the integral components of the master's educational process. It serves to consolidate and deepen the theoretical knowledge acquired during the coursework, to develop skills in problem formulation, data analysis, drawing conclusions, and to enhance the ability to work independently.

The scientific internship for master's students is organized in accordance with the **State Educational Standard** and the approved **curriculum** for the respective specialization. It represents a direct continuation and an essential part of the educational process.

The internship plays a crucial role in the completion of the master's dissertation and in preparing students for future research activities as professional researchers.

According to the approved curriculum, the scientific internship is conducted during the fourth semester. It aims to help master's students: master the content of targeted educational programs in their field of specialization, develop scientific-research competencies, and strengthen the integration of education with science and industry. The internship is organized on the basis of the latest achievements in economics, science, technology, culture, and healthcare, and provides students with opportunities to conduct research, carry out individual scientific investigations, and perform experimental studies when necessary.

The scientific internship should enable students to:
- conduct scientific research and deepen their theoretical and practical knowledge;
- study the latest advances in their respective fields and sectors;
- develop applied professional and research competencies;
- ensure effective professional adaptation.

Master's students participating in the internship may complete the program following an individual schedule, as outlined in the academic calendar. In such cases, the organization and procedures of the internship are carried out in accordance with the relevant normative and legal regulations (Regulations on Internship).

During the scientific internship, master's students are expected to: conduct scientific research based on the latest technical and technological developments in various sectors of the economy; familiarize themselves with the newest achievements in scientific and technical progress; collect materials for preparing their master's dissertation (or parts thereof); carry out research related to their dissertation topic; perform experimental and testing work required for the dissertation (or a part of it).

The main objectives of the scientific internship are:
- to provide students with a comprehensive understanding of the forms and content of research activities;
- to help them master research methods most relevant to their field of specialization;
- to enhance their skills and abilities in conducting independent research;
- to foster the professional and personal development of future researchers.

The main objective of the internship is to gain practical experience in studying a relevant scientific problem and to select the necessary materials for the completion of the master's dissertation.

During the scientific internship, the master's student must **learn to**:
- study scientific sources related to the topic of research for use in the preparation of the master's dissertation;
- apply research methods and perform experimental work;

- understand and follow the rules for operating research equipment;
- analyze and process experimental data;
- construct and apply physical and mathematical models of the processes and phenomena related to the studied object;
- use information technologies in scientific research and work with professional software relevant to their field;
- understand the requirements for designing scientific and technical documentation.

The student must be **able to:**

- analyze, systematize, and summarize scientific and technical information related to the research topic;
- conduct theoretical or experimental research within the framework of the defined tasks;
- assess the reliability of the obtained results;
- compare the research findings with local and international analogues of the studied object;
- evaluate the scientific and practical significance of the research, as well as the technical and economic efficiency of the obtained results.

At the end of the scientific internship, the master's student must complete the master's dissertation.

The supervision and control of the internship are entrusted to the internship supervisor.

The overall methodological supervision of the scientific internship is carried out by the graduating department. The nature and form of the scientific research (theoretical study, scientific experiment, preparation of scientific and technical documentation, etc.) are agreed upon at the stage of selecting the internship placement. At the same time, a mandatory requirement for conducting the internship at a particular institution is the alignment of the internship direction with the topic of the master's dissertation.

The scientific supervisor of the master's student (if different from the internship supervisor), together with the internship supervisor, shall:

- develop the program of the scientific internship;
- take the necessary organizational measures for the implementation of the internship program;
- determine the general scheme of the internship, the internship schedule, and the working plan of the student, and systematically monitor the progress of the student's internship and work;
- provide recommendations on the study of specialized literature and research methods;
- assist students in all matters related to completing the internship and preparing the final report;
- participate in the work of the commission evaluating the final report on the results of the scientific internship.

Location and Duration of the Scientific Internship

The scientific internship is conducted in the second year of the master's program (4th semester) in accordance with the approved curriculum. Depending on the object of research, the internship may take place in: scientific laboratories of university departments, research centers, or other academic units; research institutes; schools or design organizations; enterprises and institutions.

The specific list of internship sites is determined based on bilateral agreements between the university and partner enterprises or organizations. It should be noted that the internship site may later become the student's place of employment after completing the master's program. From this perspective, it is considered particularly beneficial for a master's student to conduct their research internship at an institution where they have previously completed industrial and/or pedagogical practice during their bachelor's studies. The individual program of the master's student must be coordinated with the work plan of the host institution and defined in accordance with the goals and objectives of the scientific internship.

Within the hosting unit, individual workplaces are allocated to master's students to carry out

their internship assignments. During the internship period, students must strictly comply with all internal regulations and safety rules established in the unit and at the workplace.

Structure and content of scientific practice

The total volume of the scientific practice is **18 credits (540 hours)**. A specific program of the scientific practice (developed jointly with the scientific supervisor), as well as the scope and types of work to be performed by master's students, are determined in advance by the graduating department (scientific supervisor) and communicated to the students before the start of the practice.

The activities of master's students during the practice period are organized in accordance with the topic of the master's thesis, and the student shall:

collect, process, and analyze the necessary materials and data related to the studied problem and research topic (such as patent materials, scientific reports, technical documents, statistical data, etc.);

compile a bibliographic list;

select the research base and determine the set of research methods;

study the mathematical models of the processes and phenomena related to the studied object, as well as the rules for using research instruments and equipment;

conduct experiments (if necessary) and analyze the experimental data;

prepare and deliver a presentation of the research results.

The master's student must compare the results of the study with local and international analogues, briefly analyze the scientific and practical significance of the research, and assess the technical and economic efficiency of the obtained results.