COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Low temperature physics	

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: prof. Gediminas Juzeliūnas **Other(s):**	Department of Physics, Vilnius University, Saulėtekio al. 9/III, Vilnius

Study cycle	Type of the course unit (module)
second	optional

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
auditorial	3-rd semester	Lithuanian/english

Requirements for students	
Prerequisites: Students must have completed courses on quantum mechanics, mathematical physics, statistical physics.	**Additional requirements (if any):**

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	140	64	76

Purpose of the course unit (module): programme competences to be developed		
The course has two main objectives. Firstly the students will be acquinted with the main concepts of the low temperature physics, will learn the basics of the superconductivity and superfluidity of condensed systems, including both the phenomenological and microscopic approaches to the low temperature physics. The second objective is to show how these concepts are applied to the rapidly developing area of ultracold atomic gases cooled to the nano-Kelvin temperature range, to present the main cooling and trapping mechanisms for ultracold atoms, to explain the unique features of ultracold atomic fermions and bosons.		
Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment methods**
The basic knowledge of low temperature physics including both phenomenological and microscopic approaches to the superconductivity and superfluidity and other phenomena of low temperature physics.	Lectures, practices, seminars, self-studying.	Evaluation of seminars and written exam
The basic knowledge of the physics of ultracold atoms, single and many body properties of the bosonic and fermionic ultracold atomis gases.		
Skills in solving various problems of low temperature systems.		

Content: breakdown of the topics	Contact hours							Self-study work: time and assignments	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work placement	**Contact hours**	**Self-study hours**	**Assignments**
1. Basic properties of superconductivity: a. Introduction and historical remarks b. London model c. Meissner effect d. Phase coherence e. Magnetic flux quantization f. Energy gap and coherence length	4		4				**8**	**10**	Read literature on the topic
2. Elements of Ginzburg-Landau theory: a. Landau theory of phase transitions b. Ginzburg-Landau equations c. Coherence length and penetration depth	3		3				**6**	**7**	Read literature on the topic
3. Microscipic theory of superconductivity: a. Landau Fermi liquid and Landau criterion b. Phonon-mediated electron attraction c. Cooper pairs d. Bardeen, Cooper and Schrieffer (BCS) model e. Gap equation and condensation energy f. Bogolubov quasiparticles g. Bogolubov–deGennes equations	5		5				**10**	**12**	Read literature on the topic
4. Andreev reflection: a. Normal-superconducting interface b. Transmission and reflection amplitudes c. Andreev equations d. Andreev bound states	3		3				**6**	**7**	Read literature on the topic
5. Josephson effect and weak links: a. Weakly coupled quantum systems b. D.C.and A.C. Josephson effects	2		2				**4**	**5**	Read literature on the topic
6. Atom trapping and cooling: a. Trapping and cooling mechanisms b. Creating of optical lattices	3		3				**6**	**7**	Read literature on the topic
7. Atomic Bose-Einstein condensates (BEC) and degenerate Fermi gases a. Off-diagonal long-range order b. Hydrodynamics theory c. Bogoliubov theory d. BEC-BCS crossover e. Topological excitations	4		4				**8**	**10**	Read literature on the topic
8. Optical Lattices a. Band structure b. Hubbard model c. Quantum phase transitions	4		4				**8**	**9**	Read literature on the topic
9. Topological bands a. Hexagonal lattice and Dirac points b. Haldane model c. Topological phases for periodically driven lattices	4		4				**8**	**9**	Read literature on the topic
Total	**32**		**32**				**64**	**76**	

Assessment strategy	Weight,%	Deadline	Assessment criteria
Seminar	40 %	15-16 week of the semester	Excellence in problem solution, scientific literature overview, presentations. Maximum 4 points
Exam	60 %	Exam session	Perfect knowledge of the subject. Maximal evaluation – 6 points
Final evaluation			Seminar eval. + exam evaluation

Author	Year of publication	Title	Issue of a periodical or volume of a publication	Publishing place and house or web link
Compulsary reading				
Vladimir Eltsov	2017	Theory of Superconductivity		School of Science, Aalto University, Finland https://mycourses.aalto.fi/course/view.php?id=14702&section=1 or https://mycourses.aalto.fi/pluginfile.php/450584/mod_resource/content/1/theory_sc.pdf
H. Perrin	2009	Review: Ultra cold atoms and Bose-Einstein condensation for quantum metrology	Eur. Phys. J. Special Topics 172, 37–55 (2009)	http://www-lpl.univ-paris13.fr/bec/bec/Teaching/LesHouches2007.pdf
Hui Zhai	2017	Lecture Note on Cold Atom Physics.		Institute for Advanced Study Tsinghua University, Beijing, China
Papildoma literatūra				
Optional reading				
Lev Pitaevskii and Sandro Stringari	2016	Bose-Einstein Condensation and Superfluidity		Oxford Scholarship Online
C. J. Pethick and H. Smith	2010	Bose–Einstein Condensation in Dilute Gases		Cambridge University Press