COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Nanoelectronics	

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: dr. Kristijonas Genevičius **Other(s):**	VU Faculty of Physics,

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

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
face-to-face	1st (autumn) semester	Lithuanian

Requirements for students	
Prerequisites: Solid State Physics, Introduction to Quantum Mechanics, Solid State Electronics	**Additional requirements (if any):**

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	140	48	92

Purpose of the course unit (module): programme competences to be developed		
To demonstrate how and why electron behavior in nanostructures is different from the behavior in the bulk; provide base knowledge of the mesoscopic - nanoscopic physics, electronics and technology, present the introduction to devices of modern (future) electronics, develop critical and analytical thinking.		
Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment methods**
Background knowledge that helps to understand the peculiarities of nano-structures and the nature of nano-phenomena and their potential usage in future electronics.	Lectures, seminars, self-study.	Presentations and discussions during seminars, exam.
Introduction to existing industrial and laboratory nano-technologies and development of the ability, which will help to select technology for sample preparation in practice.		
Presentation of new directions in electronics, which will be useful in further studies.		
Ability of the analytical investigation and critical evaluation of the provided material.		Presentations and discussions during seminars

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. **Introduction - object of the studies, main goals and problems.**	4		1				**5**	**8**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
2. **Main phenomena in nanoelectronics.** Quantum confinement, ballistic transport, quantum interference, quantization of the conductivity, tunneling.	2						**2**	**9**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
3. **Elements of the small systems.** Free surface and boundaries between different materials, superlattices, modeling of the atomic configurations.	2						**2**	**3**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
4. **Structures confined by intrinsic and external field.** Quantum wells, systems with modulated doping, systems with delta doping profile, metal-dielectric- semiconductor, structures with spitted gate.	2		4				**6**	**13**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
5. **Traditional techniques for thin films fabrication.** Chemical vapor deposition, molecular beam epitaxy.	1						**1**	**1**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
6. **Scanning probe techniques.** Main principles, engineering at atomic scale, local oxidation, local chemical vapor deposition.	3		1				**4**	**7**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
7. **Nanolithography.** E-beam lithography, profiling of resist with scanning probe, nanostamping, comparison of nanolithography methods.	3		1				**4**	**7**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
8. **Self-organization.** Main principles, self-organization in the bulk, self-organization during epitaxy, Langmuir- Blodgett films, perspectives of organic electronics and devices.	4		3				**7**	**12**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
9. **Formation of the nanostructured materials.** Porous silicon, porous aluminum oxide and structures formed using it, carbon nanotubes and graphene	2		3				**5**	**12**	Analysis of materials given at lectures, reading complimentary literature and preparation for

									seminars
10. **Charge carriers transport along potential barrier.** Phase interference, volt-ampere characteristics of the nanostructures, negative resistance, devices based on phase interference.	3						**3**	**4**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
11. **Tunneling of charge carriers.** Coulomb blockade, single electron tunneling, single electron devices, resonance tunneling, devices based on resonance tunneling.	4		1				**5**	**8**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
12. **Spin dependent charge carrier's transport.** Tunneling, manipulation of the spins of charge carriers in semiconductors, Kondo effect, spintronic devices.	2		2				**4**	**8**	Analysis of materials given at lectures, reading complimentary literature and preparation for seminars
Total	**32**		**16**				**48**	**92**	

Assessment strategy	**Weight, %**	**Deadline**	**Assessment criteria**
Seminars	25	all semester	Ten points evaluation system. **S_1**: points for presentation at the seminars: understanding of the topic, answers to the questions, ability to keep up discussion. **S_2**: points for active participation in discussion during seminars. **$S=0.2\times S_1+0.05\times S_2$**
Exam	75	January	Exam consists of three questions: one main and two short questions, every question is evaluated using ten points system. The focus is on the student's ability to consistently and clearly formulate answers and justify his or her opinion. **E_1**: answer to the main question. **E_2, E_3**: answers to the short question. **$E=0.35\times E_1+0.2\times E_2+0.2\times E_3$**

Author	**Year of publication**	**Title**	**Issue of a periodical or volume of a publication**	**Publishing place and house or web link**
Compulsary reading				
E. L. Wolf	2008	Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience		https://onlinelibrary.wiley.com/doi/book/10.1002/9783527618972
C. Dupas, P. Houdy, M. Lahmani	2007	Nanoscience: nanotechnologies and nanophysics		https://www.springer.com/la/book/9783540286165
Optional reading				
V. Karpus	2004	Dvimačiai elektronai		Vilnius; Ciklonas
W. Fahrner	2005	Nanotechnology and nanoelectronics		https://www.springer.com/us/book/9783540224525
M. Grundmann	2006	The physics of semiconductors an introduction including devices and nanophysics		https://www.springer.com/br/book/9783540346616
Y. Imry	2001	Introduction to Mesoscopic Physics		https://global.oup.com/academic/product/introduction-to-mesoscopic-physics-

				9780198507383?cc=lt&lang=en&
R. Tsu	2011	Superlattice to nanoelectronics		https://www.sciencedirect.com/science/book/9780080968131
P. N. Prasad	2004	Nanophotonics		https://onlinelibrary.wiley.com/doi/book/10.1002/0471670251
S. Oda, D. Ferry.	2005	Silicon Nanoelectronics		https://www.crcpress.com/Silicon-Nanoelectronics/Oda-Ferry/p/book/9780824726331
A. Nabok	2005	Organic and Inorganic Nanostructures		http://us.artechhouse.com/Organic-and-Inorganic-Nanostructures-P866.aspx
Ch. P. Poole, F. J. Owens	2003	Introduction to Nanotechnology		https://www.wiley.com/en-us/Introduction+to+Nanotechnology-p-9780471079354