Electric and thermoelectric transport at the nanoscale

Educational subject description sheet

Basic information

Study programme Fizyka (Physics of Advanced Materials for Energy Processing) **Speciality** - **Organizational unit** Faculty of Physics **Study level** Second-cycle programme **Study form** Full-time **Education profile** General academic	**Didactic cycle** 2023/24 **Subject code** 04FENS.21S.03247.23 **Lecture languages** English **Course type** Elective **Block** specialty subjects

Subject coordinator	Ireneusz Weymann
Lecturer	Ireneusz Weymann

Period	**Activities and hours**	**Number of ECTS points**
Semester 1	• Lecture: 30, Graded credit	3

Goals

Code	Goal
C1	The aim of the course is to teach the basic formalism and discuss the effects emerging in electric and thermoelectric transport properties of nanostructures.

Subject learning outcomes

Code	Outcomes in terms of	Learning outcomes	Examination methods
Knowledge – Student:			
W1	knows the basic trends in nanoscience and quantum effects that emerge in transport through nanostructures	FEN_K2_W01, FEN_K2_W02, FEN_K2_W03, FEN_K2_W04	Written colloquium, Oral colloquium
W2	knows the role of nanotechnology in the development of civilization	FEN_K2_W05	Written colloquium, Oral colloquium
W3	knows the basic formalism describing electric and thermoelectric transport in nanostructures	FEN_K2_W02, FEN_K2_W03	Written colloquium, Oral colloquium
Skills – Student:			
U1	is able to study the transport properties of nanostructures using simple models and methods	FEN_K2_U01	Written colloquium, Oral colloquium
Social competences – Student:			
K1	is ready to discuss contemporary challenges of modern nanoscale technologies	FEN_K2_K01, FEN_K2_K02	Written colloquium, Oral colloquium

Study content

No.	Course content	Subject learning outcomes	Activities
1.	Introduction: Electric and thermoelectric properties: classical versus quantum	W1, W2, W3, U1, K1	Lecture
2.	Quantum interference effects in low-dimensional systems, transmission through a double tunnel barrier, Breit-Wigner formula	W1, W2, W3, U1, K1	Lecture
3.	Scattering theory for electric and thermoelectric transport. Landauer formula	W1, W2, W3, U1, K1	Lecture
4.	Linear response theory: Seebeck coefficient, heat conductance and thermoelectric figure of merit.	W1, W2, W3, U1, K1	Lecture
5.	Thermoelectricity as a probe of correlations in nanoscale systems, nanoscale heat engines	W1, W2, W3, U1, K1	Lecture
6.	Single-electron charging effects, Coulomb blockade, Kondo effect	W1, W2, W3, U1, K1	Lecture

Additional information

Activities	Teaching and learning methods and activities
Lecture	Lecture with a multimedia presentation of selected issues, Conversation lecture, Problem-based lecture

Activities	Credit conditions
Lecture	The students have to pass the written exam, which will be followed by optional oral exam and discussion. Assessment criteria: Very good (bdb; 5,0): 90-100% of final score Good plus (+db; 4,5): 80-89% of final score Good (db; 4,0): 60-79% of final score Satisfactory plus (+dst; 3,5): 60-69% of final score Satisfactory (dst; 3,0): 50-59% of final score Unsatisfactory (ndst; 2,0): 0-49% of final score

Literature

Obligatory

1. Giuliano Benenti, Giulio Casati, Keiji Saito, and Robert S. Whitney, Fundamental aspects of steady-state conversion of heat to work at the nanoscale, Physics Reports 694, 1 (2017)
2. Yuli Nazarov and Yaroslav Blanter, Quantum Transport (Cambridge 2009).
3. Massimiliano Di Ventra, Electrical Transport in Nanoscale Systems (Cambridge 2008)
4. Tero Heikkila, The Physics of Nanoelectronics – Transport and Fluctuation Phenomena at Low Temperatures (Oxford Univ. Press 2013)

Calculation of ECTS points

Activities	Activity hours*
Lecture	30
Preparation for the exam	40
Preparation for classes	20
Student workload	**Hours** 90
Number of ECTS points	**ECTS** 3

* academic hour = 45 minutes

Efekty uczenia się dla kierunku

Kod	Treść
FEN_K2_K01	The graduate is ready to critically evaluate own knowledge and received content
FEN_K2_K02	The graduate is ready to recognize the importance of knowledge in solving cognitive and practical problems and seeking expert opinion (also from other scientific disciplines) to overcome difficulties during independent problem solving
FEN_K2_U01	The graduate can use their knowledge to formulate and solve complex and unusual problems in the field of physical sciences; select and apply appropriate methods and tools necessary to solve a given problem (including advanced IT techniques), as well as adapt existing methods and tools or develop completely new ones
FEN_K2_W01	The graduate knows and understands in-depth selected facts, phenomena, concepts and theories specific to physics and complex relationships between them (constituting advanced general knowledge in the field of physical sciences and representing both key and other selected issues in the field of advanced detailed knowledge in this discipline)
FEN_K2_W02	The graduate knows and understands in-depth selected research methods and tools as well as mathematical models used in physics
FEN_K2_W03	The graduate knows and understands in-depth selected computational methods and information technology tools and techniques used to solve complex problems in physics
FEN_K2_W04	The graduate knows and understands main development trends in the discipline of physical sciences
FEN_K2_W05	The graduate knows and understands the role of physical sciences in the context of fundamental dilemmas and challenges of modern civilization