

Introduction to Molecular Magnetism Educational subject description sheet

Basic information

Study programme Fizyka Speciality INFORMACIA KWANTOWA I SPINTRONIKA		Didactic cycle 2023/24 Subject code 04FIZIKSS.22KU.04355.23	
Organizational unit Faculty of Physics		Lecture languages English	
Study level Second-cycle programme		Course type Elective	
Study form Full-time Education profile		Block Complementary major subjects	
General academic			
Subject coordinator	Piotr Kozłowski		
Lecturer	Piotr Kozłowski		
Period Semester 2	Activities and hours • Lecture: 30, Exam • Seminar: 15, Graded credit		Number of ECTS points 4

Goals

Code	Goal
C1	To acquaint students with a class of magnetic materials based on non-interacting magnetic molecules.
C2	To acquaint students with experimental and theoretical methods used in molecular magnetism.

Subject learning outcomes

Code	Outcomes in terms of	Learning outcomes	Examination methods
Knowledge	e - Student:		
W1	understands the origin of magnetism in molecules and the difference between the bulk and molecular magnetic materials.	FIZ_K2_W01, FIZ_K2_W04, FIZ_K2_W05	Written exam, Oral exam
W2	knows and understands experimental techniques that can be used to characterize molecular magnets.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Written exam, Oral exam
W3	knows and understands a spectrum of theoretical techniques that can be used to model molecular magnets.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Written exam, Oral exam
W4	knows and understands different phenomena, such as for instance relaxation processes, responsible for peculiar properties of molecular magnets.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04	Written exam, Oral exam
W5	knows and understands potential applications of molecular magnets in spintronics/electronics, quantum information processing, magnetic refrigeration.	FIZ_K2_W04, FIZ_K2_W05	Written exam, Oral exam, Project
Skills - Student:			
U1	can recognize main types of molecular magnets.	FIZ_K2_U02, FIZ_K2_U04	Written exam, Oral exam
U2	is able to model simple molecular magnets.	FIZ_K2_U01, FIZ_K2_U02, FIZ_K2_U03	Written exam, Oral exam, Project
U3	reads with understanding and refers to the literature on molecular magnetism.	FIZ_K2_U02, FIZ_K2_U04, FIZ_K2_U05, FIZ_K2_U07	Project

Study content

No.	Course content	Subject learning outcomes	Activities
1.	Historical introduction, reasons for investigating molecular magnetism, field overview.	W1, W4, U3	Lecture
2.	The origin of magnetism in molecules: spin and orbital magnetic moments, dipolar, exchange, super exchange and double exchange interactions, crystal field.	W1, W3, U3	Lecture
3.	Experimental characterization of molecular magnets: DC and AC SQUID, EPR, INS, NMR, torque magnetometry, calorimetry.	W2, W4, U3	Lecture, Seminar
4.	Molecular magnets based on transition metals.	W1, U1, U3	Lecture, Seminar
5.	Single ion magnets based on lanthanides.	W1, U1, U3	Lecture, Seminar
6.	Molecular magnets with mixed valence and itinerant electrons.	W1, U1, U3	Lecture, Seminar
7.	Theoretical methods: effective Hamiltonian, diagonalization, quantum transfer matrix, DFT, ab initio.	W3, W4, U2, U3	Lecture, Seminar
8.	Relaxation phenomena: Quantum tunneling of magnetization, Raman, direct and Orbach processes.	W4, U3	Lecture, Seminar
9.	Single molecule magnets and application in quantum computing.	W4, W5, U1, U3	Lecture, Seminar

No.	Course content	Subject learning outcomes	Activities
10.	Electronic/spin transport through molecular magnets.	W4, U3	Lecture, Seminar
11.	Applications in: electronics/spintronics, molecular refrigeration.	W5, U3	Lecture, Seminar
12.	Tuning properties of molecular magnets for practical purposes.	W1, W4, U2, U3	Lecture, Seminar

Additional information

Activities	Teaching and learning methods and activities	
Lecture	Lecture with a multimedia presentation of selected issues, Problem-based lecture, Discussion, Case study, Problem-based learning	
Seminar	Case study, Research method (scientific inquiry), Project method	

Activities	Credit conditions
Lecture	The exam will be oral or written depending on the number of students. The student will have to gain at least 55% of points. The grades are assigned according to the scheme: 55-64% - 3 65 - 73% - 3.5 74 - 82% - 4 83 - 91% - 4.5 92 - 100% - 5
Seminar	Presentation of a project/article/problem. The student has to prepare and present in the form of multimedia presentation one chosen topic. The grades are assigned according to the scheme: 55-64% - 3 65 - 73% - 3.5 74 - 82% - 4 83 - 91% - 4.5 92 - 100% - 5

Literature

Obligatory

1. D. Gatteschi, R. Sessoli, J. Villain, Molecular Nanomagnets, Oxford University Press, 2006.

Optional

- 1. J. Tang, P. Zhang, Lanthanide Single Molecule Magnets, 2015th ed., Springer-Verlag Berlin Heidelberg, 2015.
- 2. J.F. Bartolomé Fernando Luis Julio Fernández ed., Molecular Magnets Physics and Applications, Springer, 2014.

Calculation of ECTS points

Activities	Activity hours*
Lecture	30
Seminar	15

Preparation for the exam	15
Preparation of a project	15
Reading the indicated literature	10
Preparation for classes	15
	Hours
Student workload	100
Number of ECTS points	ECTS 4

* academic hour = 45 minutes

Efekty uczenia się dla kierunku

Kod	Treść
FIZ_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
FIZ_K2_U02	The graduate can find the necessary information in the professional literature, databases and other sources, in particular in scientific journals basic to physics, and perform critical analysis, synthesis and creative interpretation of the collected information
FIZ_K2_U03	The graduate can formulate and test hypotheses related to simple research problems in physics (plan and perform observations, experiments, theoretical calculations or computer simulations and critically evaluate and discuss the results obtained)
FIZ_K2_U04	The graduate can prepare, for various audiences, oral presentations and written studies presenting specialized topics in the field of physical sciences in a communicative way, as well as debate on such topics
FIZ_K2_U05	The graduate can use English in accordance with the requirements set out for level B2+ of the Common European Framework of Reference for Languages, as well as specialist English terminology in the field of physical sciences
FIZ_K2_U07	The graduate can independently determine the directions of further learning and implement a self-education program, learn throughout lifetime using the available international literature and be able to guide others in this regard
FIZ_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)
FIZ_K2_W02	The graduate knows and understands in-depth selected research methods and tools as well as mathematical models used in physics
FIZ_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
FIZ_K2_W04	The graduate knows and understands main development trends in the discipline of physical sciences
FIZ_K2_W05	The graduate knows and understands the role of physical sciences in the context of fundamental dilemmas and challenges of modern civilization