UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU

# Introduction to Molecular Magnetism

Educational subject description sheet

## Basic information

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|---|---|
| **Study programme**<br>Fizyka | **Didactic cycle**<br>2023/24 |
| **Speciality**<br>INFORMACJA KWANTOWA I SPINTRONIKA | **Subject code**<br>04FIZIKSS.22KU.04355.23 |
| **Organizational unit**<br>Faculty of Physics | **Lecture languages**<br>English |
| **Study level**<br>Second-cycle programme | **Course type**<br>Elective |
| **Study form**<br>Full-time | **Block**<br>Complementary major subjects |
| **Education profile**<br>General academic | |

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|---|---|
| **Subject coordinator** | Piotr Kozłowski |
| **Lecturer** | Piotr Kozłowski |

| **Period** | **Activities and hours** | **Number of ECTS points** |
|---|---|---|
| Semester 2 | • Lecture: 30, Exam<br>• Seminar: 15, Graded credit | 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 – 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:<br>55-64% - 3<br>65 - 73% - 3.5<br>74 - 82% - 4<br>83 - 91% - 4.5<br>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:<br>55-64% - 3<br>65 - 73% - 3.5<br>74 - 82% - 4<br>83 - 91% - 4.5<br>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 |
| | |
| **Student workload** | **Hours**<br>100 |
| **Number of ECTS points** | **ECTS**<br>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 |