Magnetism and Magnetic Materials
Educational subject description sheet

Basic information

Study programme Fizyka **Speciality** BIOFIZYKA MOLEKULARNA **Organizational unit** Faculty of Physics **Study level** Second-cycle programme **Study form** Full-time **Education profile** General academic	**Didactic cycle** 2023/24 **Subject code** 04FIZBMOS.24S.04362.23 **Lecture languages** English **Course type** Elective **Block** specialty subjects
Subject coordinator	Maciej Krawczyk
Lecturer	Maciej Krawczyk

Period	**Activities and hours**	**Number of ECTS points**
Semester 3	• Lecture: 30, Exam • Seminar: 15, Graded credit	4

Goals

Code	Goal
C1	Introduce students to the physics of magnetism, magnetic materials, and magnetization dynamics.
C2	Making students aware of the problems with the current research topics and open questions in the physics of magnetism.
C3	Familiarize students with current applications and prospects for future magnetic materials and magnonics development.
C4	Developing the ability to read and understand scientific papers on the physics of magnetism, draw conclusions, formulate research problems, and analyze potential ways to solve them.

Subject learning outcomes

Code	Outcomes in terms of	Learning outcomes	Examination methods
Knowledge - Student:			
W1	Knows the principles of electromagnetic and magnetostatic principles related to the magnetic field and magnetic materials. Knows the basic equations describing magnetostatic potential and magnetic field distribution.	FIZ_K2_W01	Oral exam
W2	Knows the main directions of development of research and technologies related to magnetism and their contribution to the generation and saving of electricity.	FIZ_K2_W04, FIZ_K2_W05	Oral exam, Report, Multimedia presentation
W3	Knows the basic principles of experimental methods used to study magnetic materials and the dynamics of magnetization and is able to indicate their limitations.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W04, FIZ_K2_W05	Oral exam, Project, Report, Multimedia presentation
W4	Knows the selected models used to describe the magnetism, magnetization dynamics, and spin-wave dynamics in magnetic materials.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03, FIZ_K2_W04	Oral exam, Project, Report, Multimedia presentation
W5	Knows the different types of magnetic materials, stable magnetization arrangement, magnetization textures that exist in solids, the types of interactions responsible for their stabilization, and the models for describing them.	FIZ_K2_W01, FIZ_K2_W02, FIZ_K2_W03	Oral exam, Report, Multimedia presentation
W6	Knows selected topics of the current research in magnetism, and can explain their main principles, e.g., artificial spin ice, magnonics, and magnetic cellular quantum automata.	FIZ_K2_W02, FIZ_K2_W03, FIZ_K2_W04, FIZ_K2_W05	Oral exam, Project, Report, Multimedia presentation
Skills – Student:			
U1	Uses basic theoretical models to qualitatively describe interactions that exist in magnetic materials, can identify different energy terms, and can describe magnetic properties related to these interactions.	FIZ_K2_U02, FIZ_K2_U03	Oral exam, Project, Report, Multimedia presentation, Presentation of the art work
U2	Can identify the types of interactions responsible for stabilizing different magnetization textures.	FIZ_K2_U01, FIZ_K2_U03	Oral exam, Project, Multimedia presentation, Presentation of the art work
U3	Demonstrates the reading of research articles with understanding and ability to present the outcomes, summary, and the importance of research in writing and oral presentations. Show the ability to work in collaboration in the group.	FIZ_K2_U02, FIZ_K2_U03, FIZ_K2_U04, FIZ_K2_U05, FIZ_K2_U06, FIZ_K2_U07	Project, Report, Multimedia presentation, Presentation of the art work
U4	Can formulate a research problem and indicate the method and basic methodological approach to its solution.	FIZ_K2_U03, FIZ_K2_U05, FIZ_K2_U07	Project, Report, Multimedia presentation, Presentation of the art work

Study content

No.	Course content	Subject learning outcomes	Activities
1.	Overview of magnetism, magnetic materials, and the current topics of research and technology development.	W1, W6	Lecture, Seminar
2.	Basic laws of magnetostatics and electrodynamics related to magnetism, magnetic field, magnetostatic potential, magnetic moment, magnetic dipole, magnetization, and magnetic torque. Exemplary applications of permanent magnets and soft magnets.	W1, W2, W3, U1, U2	Lecture, Seminar
3.	Magnetic materials: paramagnetism, ferromagnetism/antiferromagnetism and diamagnetism. Fundamental concepts of magnetism, interactions, and complexity.	W2, W6, U2, U3, U4	Lecture, Seminar
4.	Remagnetization process in ferromagnetic materials, single-domain grains, hysteresis, complex magnetization textures, open questions, and actual investigations: super-paramagnets and super-ferromagnets, artificial spin-ice systems, frustration, and stability.	W2, W4, W5, W6, U1, U2, U3	Lecture, Seminar
5.	Fundamentals: the origin of magnetism in solids, theoretical models and numerical methods used in computations of properties of the magnetic materials, micromagnetic approach.	W2, W4, W5, W6, U2	Lecture, Seminar
6.	Magnetic domains: types and interactions determining their stability.	W1, W2, W3, W5, U2	Lecture, Seminar
7.	Experimental methods for characterization of magnetic materials, magnetization textures, and magnetization dynamics. Current trends and needs.	W1, W2, W6, U3, U4	Lecture, Seminar
8.	Magnetization dynamics, micromagnetism, Landau-Lifshit equation, damping.	W2, W4, W6, U1, U3	Lecture, Seminar
9.	Magnonics, wave phenomena in ferromagnets and antiferromagnets, spin wave dynamics in thin films, characteristic dispersion relationships, detection techniques, and possible applications.	W5, W6, U2, U3	Lecture, Seminar

Additional information

Activities	Teaching and learning methods and activities
Lecture	Lecture with a multimedia presentation of selected issues, Conversation lecture, Work with text, Case study
Seminar	Conversation lecture, Discussion, Work with text, Problem-based learning, Work in groups

Activities	Credit conditions
Lecture	The condition for taking the Lecture exam is passing the Seminar. The final grade will be based on the average from the report part and the oral exam [(oral exam points + report points)/2], but each part independently has to receive a score larger than 2,0. The report (15 000 – 17 000 chars with spaces) will be based on the research paper(s) on one topic, selected from the provided list of research papers. The points (from 2.0 to 5.0 points) will take into account the quality of the presentation and its style, its logic, the clearness of the problem description, and its consistency. At the oral exam, everyone will receive 3 questions drawn from the knowledge topics (2 questions) and a problem task from the new research (1). The full answer for each question gives from 2 to 5 points (pt), and the final score is an arithmetic average of the obtained points. Very good (bdb; 5,0): (4.5pt - 5.0pt> Good plus (+db; 4,5): (4,0pt - 4.5pt> Good (db; 4,0): (3,5pt – 4,0pt> Satisfactory plus (+dst; 3,5): (3,0pt – 3,5pt> Satisfactory (dst; 3,0): (2,5pt – 3,5pt> Unsatisfactory (ndst; 2,0): less than 2.5pt
Seminar	The final grade will be based on the average from the report part based on at least two research papers, at least two presentations of selected topics on seminars, and taking an active part in a discussion on seminars. The report (15 000 – 17 000 chars with spaces) will be based on two research papers on one topic, it should present a critical comparison of the results of both papers. The points (from 2.0 to 5.0 points) will take into account the quality of the presentation and its style, its logic, and its consistency. Two presentations, one individual and one in the group, on the selected topic shall show the actual state of the art, define the open questions, and current topics in research or technological application related to magnetism or magnetic materials. The points (from 2.0 to 5.0 points) will take into account the quality of the presentation and its style, its logic, and its consistency, as well as discussion after the presentation. Very good (bdb; 5,0): (4.5pt - 5.0pt> Good plus (+db; 4,5): (4,0pt - 4.5pt> Good (db; 4,0): (3,5pt – 4,0pt> Satisfactory plus (+dst; 3,5): (3,0pt – 3,5pt> Satisfactory (dst; 3,0): (2,5pt – 3,5pt> Unsatisfactory (ndst; 2,0): less than 2.5pt

Literature

Obligatory

1. J. M. D. Coey, “Magnetism and magnetic materials”, (Cambridge University Press, 2009); chapters 1-13.
2. C. Kittel, ”Introduction to the solid state physics”, (PWN, Warszawa 1999 or John Wiley & Sons, Inc., Ed. 8th, 2005); two chapters related to the band structure formation and magnetism.
3. R. P. Cowburn and M. E. Welland, Room Temperature Magnetic Quantum Cellular Automata, Science 287, 1466 (2000); DOI: 10.1126/science.287.5457.1466
4. W. Ketterle and D.E. Pritchard, Trapping and focusing ground state atoms with static fields, Appl. Phys. B 54, 403406 (1992);

Optional

1. J. Stoehr, H. C. Siegemann, “Magnetism, from fundamentals to nanoscale dynamics” (Springer, 2006);
2. A. Hubert, R. Schafer, “Magnetic domains, the analysis of magnetic microstructures” (Springer, 2009);
3. Z. Guo, et al., Spintronics for Energy-Efficient Computing: An Overview and Outlook, PROCEEDINGS OF THE IEEE 109, 1398 (2021); DOI: 10.1109/JPROC.2021.3084997
4. N. D. Mermin and H. Wagner, Absence of ferromagnetism or antiferromagnetism in one- or two-dimensional isotropic Heisenberg models, Phys. Rev. Lett. 17, 1133 (1966).

Calculation of ECTS points

Activities	Activity hours*
Lecture	30
Seminar	15
Reading the indicated literature	20
Report preparation	20
Preparation of a multimedia presentation	15
Preparation for the exam	10
Student workload	**Hours** 110
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_U06	The graduate can interact with others as part of teamwork and take a leading role in such work; manage team work
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