SYLLABUS

1. Information regarding the programme

1.1 Higher education institution	Babes-Bolyai University
1.2 Faculty	of Physics
1.3 Department	Condensed Matter Physics and Advanced Technologies
1.4 Field of study	Physics
1.5 Study cycle	PhD
1.6 Study programme / Qualification	Physics

2. Information regarding the discipline

2.1 Name of the discipline	Advanced methods in the study of the condensed state						
2.2 Course coordinator	Prof.dr. Romulus Tetean, Prof.dr. Aurel Pop, Prof.dr. Iosif Deac, Prof.dr. Ioan Grosu						
2.3 Seminar coordinator	Prof.dr. Romulus Tetean, Prof.dr. Aurel Pop, Prof.dr. Iosif Deac, Prof.dr. Ioan Grosu						
2.4. Year of study	I	2.5 Semester	1	2.6. Type of evaluation	E	2.7 Type of discipline	DS

3. Total estimated time (hours/semester of didactic activities)

3.1 Hours per week	3	Of which: 3.2 course	2	3.3 seminar/laboratory	1
3.4 Total hours in the curriculum	36	Of which: 3.5 course	24	3.6 seminar/laboratory	12

Time allotment:	hours
Learning using manual, course support, bibliography, course notes	30
Additional documentation (in libraries, on electronic platforms, field documentation)	35
Preparation for seminars/labs, homework, papers, portfolios and essays	18
Tutorship	8
Evaluations	2
Other activities:	-

3.7 Total individual study hours	93
3.8 Total hours per semester	129
3.9 Number of ECTS credits	5

4. Prerequisites (if necessary)

4.1. curriculum	
4.2. competencies	

5. Conditions (if necessary)

5.1. for the course	• Course hall with blackboard, projector and software
5.2. for the seminar /lab	• Course hall with blackboard, projector, internet acces and software

activities	

6. Specific competencies acquired

Professional competencies	**C1.** Using of advanced knowledge of physics, mathematics and chemistry of solids for study in Solid State Physics and Materials Science. Capacity for analysis and synthesis of physical data, the ability to model complex phenomena. **C2.** Capitalization of physical fundamentals, of methods and tools of solid state physics and materials science for specific production activities, expertise and monitoring. Mindset multi-and interdisciplinary. **C3.** Planning and conducting experiments to assess the uncertainty and interpretation of the results. Use basic research laboratory equipment and industrial laboratory for conducting research experiments. Planning and implementation independently experiments or experimental investigations and evaluating the uncertainty of the results **C4.** Communicating complex scientific ideas, conclusions or results of a scientific project experiments. Ability to obtain and argue scientific results, the ability to produce scientific papers and to relate to the editorial board of scientific journals of the field.
Transversal competencies	**CT1.** Fulfil the professional tasks effectively and responsibly with respect for law and ethics under qualified assistance. Responsible execution of professional duties in terms of autonomy and decision-making based on self-assessment. **CT2.** Effective work in multidisciplinary team on different hierarchical levels. Implementation of activities and fulfilling specific teamwork roles on different hierarchical levels, showing initiative and entrepreneurial leadership based on promoting dialogue, cooperation positive attitudes, mutual respect, diversity and multiculturalism and continuous improvement of their activities. **CT3.** Effective use of information sources and communication resources and training assistance, both in Romanian and in a foreign language. Objective self-evaluation of the need for continues training to labour market insertion and the adaptation to dynamic requirements of labour market.

7. Objectives of the discipline (outcome of the acquired competencies)

7.1 General objective of the discipline	• Acquiring notions on the experimental and theoretical techniques and methods concerning the study of condensed matter.
7.2 Specific objective of the discipline	Acquiring the notions related to: - Determining the crystal structure of different classes of materials, both massive and nanostructured. - Determination of thermal properties of materials. - Determination of magnetic structures, of the respective magnetic moments, determination of the local magnetic properties - Analysis of surface defects - Knowledge of the specific properties of surfaces and their role in practical applications - Studying the effect of intense magnetic fields on electrical conductivity; magnetoresistance measurement - Determination of the Fermi surface (by De Haas van Alphen effect) and the electronic structure (XPS and ARPES), - Measurement of magnetic susceptibility in alternating current for determining the dynamic magnetic properties, of the phase transformations, using the nonlinear components of the complex susceptibility. - Writing in the second quantification of a series of operators and groups of

	operators. - Using the method of the equation of motion to determine the energy spectrum, in the case of multi-particle systems with interactions. - Determination of properties of many particle systems, in Hartree and Hartree-Fock approximations. - Choosing the type of measurements taking into account the specificity and sensitivity of the method - Processing and interpretation of experimental results. - Valorization of data obtained through publications. - Analysis of possible technological applications.

8. Content

8.1 Course	Teaching methods	Remarks
Determination of the crystalline structure with X-rays: X-ray diffraction. X-ray sources. High and small angle diffraction. Crystalline and non-crystalline materials. Particular aspects of small dimensional systems.	Lecture, demonstration, debate, the experiment demonstration and presentations on the computer	2 hours
X-ray absorption spectroscopy. XANES, EXAFS. EXAFS signal extraction. XPS. TEM, SEM Thermal measurements. Differential thermal analysis		2 hours
Magnetic measurements. Analysis of magnetization curves. Determining the transition temperatures and the saturation/effective magnetic moments. Electron diffraction. Neutron diffraction, □SR.		2 hours
Elements of surface physics.		2 hours
Surface Morphology and Physical Structure		2 hours
Modern methods in Surface Science		2 hours
Experimental techniques and principles of structure-related phenomena. Experimental study of the Fermi surface in metals. Electrons in high magnetic fields. Quantum oscillation and the topology of Fermi surface. De Haas-van Alphen Effect. Photoemission spectroscopy. X-ray photoelectron spectroscopy (XPS). Angle Resolved Photo Emission Spectroscopy (ARPES).		2 hours
Transport phenomena in high magnetic fields (Focus on colossal magnetoresistance). Magnetoresistance. Introductory remarks. Ordinary MR, AMR, Giant MR, Tunel MR, CMR. Colossal Magnetoresistance. Mixed valence manganites. Phase diagrams. Electrons' interaction. Double exchange interaction. Jahn-Teller distortion. Polarons. Charge/orbital ordering. Phase separation. Examples. Cryostats for magneto-transport measurements.		2 hours
Experimental techniques and principles of structure-related phenomena. Experimental study of the Fermi surface in metals. Electrons in high magnetic fields. Quantum oscillation and the topology of Fermi surface. De Haas-van Alphen Effect. Photoemission spectroscopy. X-ray photoelectron spectroscopy (XPS). Angle Resolved Photo Emission Spectroscopy (ARPES).		2 hours

Second quantization. Operators in second quantization.		2 hours
Representations. Movement equation method.		2 hours
Hartree, and Hartree-Fock aproximations.		2 hours

Bibliography

Compulsory:

1. C. Kittel, Introduction to Solid State Physics (7ed., Wiley, 1996)
2. N. W. Ashcroft, N. D. Mermin, *Solid State Physics*, Saunders, 1976
3. U. Mizutani, Introduction to the Electron Theory of Metals,Cambridge University Press 2001.
4. E.Burzo, "Fizica Fenomenelor Magnetice" vol. 1-3, Editura Academiei Române 198-1987, 1255 pag.
5. H. Alloul, Introduction to the Physics of Electrons in Solids, Springer-Verlag Berlin Heidelberg 2
6. Z. L. Wang (editor), Characteriyation of Nanophase Materials, Ed. Wiley-VCH, Weinheim, New York, Chichester, Brisbane, Singapore, Toronto, 2000
7. F.J.Himpsel, J.E.Ortega, G.J.Mankey, R.F.Willis, Magnetic nanostructures, Advances in Phys, Vol.47, Nr. 4, 511-597, 1998
8. Z.I.Wang, Elastic and Inelastic Scattering in Electron Diffraction and Imaging, Plenum Pub.Co, New York, 1995
9. Hans Luth ,Surface and Interfaces of Solids by Springer-Verlag 2001 (4th. Edition)
10. Harald Ibach, Physics of Surfaces and Interfaces, Springer-Verlag Berlin Heidelberg 2006.
11. K. Oura et al., Surface Science, Springer Verlag, 2003
12. J. M. D. Coey, M. Viret, and S. von Molnar, Mixed-valence manganites, Adv. Phys. 48, 167 (1999)
13. E. Dagotto, Nanoscale Phase Separation and Colossal Magnetoresistance, Springer, 2003
14. D. C. Tsui, de Haas—van Alphen Effect and Electronic Band Structure of Nickel, Phys. Rev. **164**, 669 – Published 10 December 1967
15. Andrea Damascelli, Probing the Electronic Structure of Complex Systems by ARPES, Physica Scripta. Vol. T109, 61–74, 2004
16. F. Gömöry, Characterization of High-Temperature Superconductors by AC Susceptibility Measurements, Superconductor Science and Technology 10(8):523 · January 1999.
17. A.H. Morrish, The Physical Principles of Magnetism, John Wiley & Sons (New York, 1965).
18. M. S. Suzuki, I. S. Suzuki, https://www.researchgate.net/publication/269929759
19. D. Pines, P. Nozieres, "The Theory of Quantum Liquids", vol.I, Benjamin, New York, (1966)
20. I.Tifrea, I.Grosu, M.Crisan, "Metode cuantice pentru studiul sistemelor cu multe particule. Aplicatii la sisteme fermionice si bosonice", Presa Universitara Clujeana, (2005)
21. I.Grosu, I.Tifrea, "Teoria materiei condensate. Probleme", Casa Cartii de Stiinta, Cluj, (2006)

Optional:

1. Journals on condensed matter physics
2. http://xxx.lanl.gov/archive/cond-mat

8.2 Seminar / laboratory	Teaching methods	Remarks
Particular aspects of X-ray diffraction in small dimensional systems.	Presentations. Correlations between experimental results and theoretical models. Discussions.	2 hours
Magnetic structures. Local order and long range order respectively.		1 hour
Surface analysis:Low Energy Electron Diffraction (LEED: Reflection High-Energy Electron Diffraction (RHEED); Electron Spectroscopy Methods.		3 hours
Processing the ac susceptibility experimental data.		1 hour
Processing the magneto-transport experimental data.		2 hours
Two-particles interaction, lattice vibrations and Fermi systems in second quantization		3hours

Bibliography

1. E.Burzo, "Fizica Fenomenelor Magnetice" vol. 1-3, Editura Academiei Române 198-1987, 1255 pag.
2. H. Alloul, Introduction to the Physics of Electrons in Solids, Springer-Verlag Berlin Heidelberg 2
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Chichester, Brisbane, Singapore, Toronto, 2000
4. F.J.Himpsel, J.E.Ortega, G.J.Mankey, R.F.Willis, Magnetic nanostructures, Advances in Phys, Vol.47, Nr. 4, 511-597, 1998
5. Harald Ibach, Physics of Surfaces and Interfaces, Springer-Verlag Berlin Heidelberg 2006.
6. K. Oura et al., Surface Science, Springer Verlag, 2003
7. U. Mizutani, Introduction to the Electron Theory of Metals,Cambridge University Press 2001.
8. A P Ramirez, Colossal magnetoresistance, J. Phys.: Condens. Matter 9 (1997) 8171–8199
9. S. Kundu and T. K. Nath, Probing the magnetic state by linear and non linear ac magnetic susceptibility measurements in under doped manganite $Nd_{0.8}Sr_{0.2}MnO_3$, nsmo82_arxiv.
10. I.Tifrea, I.Grosu, M.Crisan, "Metode cuantice pentru studiul sistemelor cu multe particule. Aplicatii la sisteme fermionice si bosonice", Presa Universitara Clujeana, (2005)
11. 11. I.Grosu, I.Tifrea, "Teoria materiei condensate. Probleme", Casa Cartii de Stiinta, Cluj, (2006)

9. Corroborating the content of the discipline with the expectations of the epistemic community, professional associations and representative employers within the field of the program

- The content of the discipline is in accordance with the subjects which are studied in the same field in Romanian and foreign universities and with the specific demands of research institutes, economy and labour market.

10. Evaluation

Type of activity	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Share in the grade (%)
10.4 Course	Understanding of the physical phenomena in condensed matter physics and capacity to make connexion between the results obtained by different techniques.	Participation, questions, answers	50 %
10.5 Seminar/lab activities	Preparation and presentation on a subject related to advanced methods in condensed matter physics.The quality of the presentation,	Direct evaluation	50%
10.6 Minimum performance standards			
➢ Main techniques used for characterization ➢ Choosing, planning and carrying out an experimental method for a certain kind of characterization.			

Signature of course coordinator
Prof.dr. Romulus Tetean

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Date of approval

21.09.2020

Signature of the head of department

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