COURSE DESCRIPTION

Magnetic resonance methods in biomedical research

Academic year 2026-2027

1. Programme-related data

1.1. Higher Education Institution	Babeş-Bolyai University
1.2. Faculty	Faculty of Physics
1.3. Department	Doctoral School of Physics
1.4. Field	Physics
1.5. Level of study	Doctorate
1.6. Degree programme / Qualification	Doctoral training / PhD in Physics
1.7. Form of education	Full-time, State-funded

2. Course-related data

2.1. Course title	Magnetic resonance methods in biomedical research			Course code	MRMIBMR
2.2. Course coordinator	Prof.dr. Grigore Damian, Prof.dr. Mihai Todica, Prof.dr. Radu Fechete				
2.3. Seminar coordinator	Prof.dr. Grigore Damian, Prof.dr. Mihai Todica, Prof.dr. Radu Fechete				
2.4. Year of study	1	2.5. Semester	1	2.6. Type of assessment	Exam
2.7. Course status	Optional			2.8. Course type	Specialisation subject

3. Total estimated time (hours per semester of teaching activities)

3.1. Number of hours per week	3	of which: 3.2. course	2	3.3. seminar/ laboratory/ project	1
3.4. Total of hours in the curriculum	36	of which: 3.5. course	24	3.6. seminar/ laboratory	12
Time allocation for individual study (IS) and self-taught activities (ST)					hours
Learning from textbooks, course materials, bibliography, and notes (IS)					34
Additional research in the library, on subject-specific electronic platforms, and on-site					24
Preparing seminars/ laboratories/ projects, assignments, reports, portfolios, and essays					15
Tutoring (professional guidance)					12
Examinations					4
Other activities					0
3.7. Total hours of individual study (IS) and self-taught activities (ST)				89	
3.8. Total hours per semester				125	
3.9. Number of credits				10	

4. Prerequisites (where applicable)

4.1. curriculum-related	Physics of atoms and molecules, Quantum mechanics, Numerical methods, Calculus, Algebra
4.2 skills-related	- computational skills for image processing - skills in using programming environments and graphical applications - computational skills for data (signal) acquisition and processing

5. Specific conditions (where applicable)

5.1. course-related	Course hall, appropriate board, projector, dedicated software, computer
5.2. seminar/laboratory-related	Course hall, appropriate board, projector, dedicated software, computer network, dedicated laboratory

6.1. Competencies resulting from the completion of the degree programme *(as referred to in the curriculum)*[1]

Professional competencies	
Competency code	**Competency**
PC1	Graduated PhD student has the ability to acquire modern concepts and models of molecular dynamics.
PC2	Graduated PhD student has the abilities to build molecular dynamic models and prepare input data for numerical simulations and to correlation of theoretical and simulated data with experimental ones; to use and adapt software packages (Processing, JavaScript, and Python) for data analysis and processing. Use of automated computer systems for processing and extracting data from 2D digital images.
PC3	Graduated PhD student has the ability to use appropriate models for calculating molecular magnetic resonance (NMR, EPR) properties, to operate with the principles of NMR image data processing, to analyse and synthesize data; the ability to model the effect of external factors (RF pulses, gradients) on images.
PC4	Graduated PhD student has the capacity to conduct rigorous literature reviews, critically evaluate scientific publications, and identify innovative research directions.
PC5	Graduated PhD student has competence in preparing scientific manuscripts according to international standards, presenting results at scientific conferences, and effectively communicating research findings to the scientific community.
PC6	Graduated PhD student has the ability to integrate concepts and methodologies from related fields (chemistry, materials science, engineering, computer science and biology) to address complex scientific problems.
Transversal competencies	
Competency code	**Competency**
TC1	Graduated PhD student has the capacity to collaborate effectively within diverse research teams, communicate across cultures, and contribute to international research initiatives.
TC2	Graduated PhD student has knowledge and application of principles of academic ethics, scientific integrity, intellectual property regulations, and good research practice.
TC3	Graduated PhD student has the ability to convey advanced physics concepts to both specialist and non-specialist audiences, including through teaching and science outreach activities.
TC4	Graduated PhD student has the capacity to work independently, make scientifically sound decisions, and assume responsibility for research outcomes.

6.2. Learning outcomes relevant to the degree programme (as referred to in the curriculum)[2]

Learning outcomes targeted by the subject		
Competency code	**Knowledge and comprehension**	**Specific academic skills**
PC1	1. Advanced knowledge at the frontier of a specialized field of physics, including a critical understanding of current theories, methodologies, experimental or computational techniques and imaging techniques.	1. Identify, formulate, and address original research questions that advance knowledge at the frontier of physics with direct impact on medical research.
PC2	2. Systematic and comprehensive understanding of fundamental physical principles and their mathematical formulation, enabling the development of new theoretical or applied research directions.	2. Design and implement complex research methodologies, selecting and adapting advanced experimental or computational approaches.

[1] The professional and/or transversal skills targeted by the subject for whom the course description is prepared will be copied from the curriculum of the degree programme. For each competency, the complete entry, including the competency code, will be copied with the exact wording that appears in the curriculum, without any changes. If no competency is copied from either of the two categories, the row corresponding to that category is deleted from the table.

[2] The learning outcomes relevant for the degree programme and targeted by the subject for whom the course description is prepared will be listed. The entries, copied without any changes from the Curriculum by subject type (Core Subject/Specialisation Subject/Complementary Subject), are listed under the corresponding competency.

PC3	3. Identify adequate experimental and computational methods applied in NMR and EPR spectroscopy and medical and biological imaging.	3. Identify and uses correct experimental and/or computational techniques.
TC1	4. Ability to identify current research trends, open scientific problems, and emerging technologies within the spectroscopy and biomedical imaging fields.	4. Critically evaluate scientific literature, synthesize information from multiple sources, and position original contributions within the international research context in the spectroscopy and biomedical imaging fields.
TC2	5. Comprehensive knowledge of ethical standards, academic integrity principles, and regulatory frameworks governing scientific research and dissemination.	5. Independently manage long-term research projects, including planning, documentation, risk assessment, and dissemination of results.

7. Subject-specific learning outcomes

Knowledge and comprehension
1. The PhD student/graduate understands and possesses advanced knowledge of the concepts, theories, and principles specific to NMR and EPR spectroscopy and medical and biomedica imaging, relaxometry and diffusometry.
2. The PhD student/graduate interprets concepts, theories, models, and principles of NMR and EPR spectroscopy and medical and biomedica imaging, relaxometry and diffusometry.
3. The PhD student/graduate identifies and understands appropriate analytical methods for investigating various problems in the field of NMR and EPR spectroscopy and medical and biomedica imaging, relaxometry and diffusometry.
4. The PhD student/graduate identifies and understands the experimental and computational methods, as well as the experimental and computational equipment, required for designing and conducting experiments, calculations and simulatons in the field of NMR and EPR spectroscopy and medical and biomedica imaging, relaxometry and diffusometry.
5. The PhD student/graduate identifies optimal analytical approaches for obtaining relevant information in accordance with the fundamental principles of NMR and EPR spectroscopy and medical and biomedica imaging, relaxometry and diffusometry.
Specific academic skills
1. The PhD student/graduate synthesizes knowledge and appropriately applies the concepts, theories, and principles specific to applications of spectroscopy and medical imaging.
2. The PhD student/graduate applies concepts, theories, models, and principles of NMR and PER spectroscopy and medical and biomedica imaging, relaxometry and diffusometry to obtain original data in the field.
3. The PhD student/graduate correlates experimental and computational methods to solve various problems in NMR and PER spectroscopy and medical and biomedica imaging, relaxometry and diffusometry, integrating results and critically interpreting the data and information obtained.
4. The PhD student/graduate applies experimental and computational methods to perform the experiments, calculations and simulations required in NMR and PER spectroscopy and medical and biomedica imaging, relaxometry and diffusometry and correctly interprets the obtained data.
5. The PhD student/graduate identifies problems that may arise in scientific research and autonomously and creatively formulates appropriate solution strategies.

8. Contents

8.1. Course	**Teaching and learning methods**	**Remarks[3]**
1. Basic theory, practice, and instrumentation for EPR continuous wave Electron Paramagnetic Resonance (EPR) spectroscopy.	Interactive lecture, Directed discussion, debate, Case-based learning, Just-in-time teaching	2 hours
2. Detection and characterization of paramagnetic species by EPR spectroscopy.		2 hours
3. Study of biomolecular systems using nitrone compounds (spin labels and spin traps) and EPR spectroscopy.		2 hours
4. The spin labeling methodology of biomolecular systems. Applications. Oximetry and EPR imaging		2 hours

[3] For example, organisational aspects, recommendations for students, specific aspects relating to the course/seminar, such as inviting experts in the field, etc.

5. The principles of two-dimensional magnetic resonance.		2 hours
6. Obtaining images using spin echoes and gradients of magnetic field.		2 hours
7. FID recording and its analysis by Fourier transform.		2 hours
8. Sign in magnetic field gradients. Measurement of the diffusion coefficient		2 hours
9. In vivo NMR spectroscopy – Static Aspects. ^{1}H NMR spectra of metabolites		2 hours
10. In vivo NMR spectroscopy – Dynamic Aspects. ^{1}H NMR relaxometry and diffusiometry. Sub-voxel water compartments. Myelin water. Biomedical examples.		2 hours
11. In vivo Magnetic Resonance Imaging. Introduction. Static and radiofrequency magnetic fields. Magnetic Field Gradients. Slice selection. Frequency and Phase encoding. Contrast in MRI. Biomedical examples.		2 hours
12. Radiofrequency pulse sequences. Single volume localization. Water and non-water suppression NMR spectroscopy. Spectra quantification. Biomedical examples.		2 hours
8.2. Seminar/ laboratory	**Teaching and learning methods**	**Remarks**
1. Spin labeling of proteins with nitroxide radicals, in the study of biological systems. Application on heme proteins.	Problem based learning, Project based learning, Inquiry guided learning, Experiential learning	2 hours
2. Detection and characterization of free radicals in biological systems. Application on the radicals generated in gamma irradiation		2 hours
3. Seminar: Larmor precession, transverse and longitudinal magnetization, relaxation of magnetization.		1 hour
4. Laboratory: Adjusting the resonance frequency of the 90 degree pulses in the case of a 7 T real RMN spectrometer		1 hour
5. Seminar: Production of linear magnetic field gradients, anti-Helmholtz coils. Spatial coding using gradient pulses.		1 hour
6. Laboratory: Adjusting the parameters of the gradient coils in the case of a Real MRI installation and obtaining one-dimensional images on phantom samples.		1 hour
7. Knowledge and application of Processing based software for the quantification of in vivo ^{1}H NMR spectra measured for various types of organs/tissues		2 hours
8. Knowledge and application of JavaScript based software for the quantification of in vivo ^{1}H NMR parameters maps (T_1, T_2, ^{1}H spin density) measured for various types of organs/tissues.		2 hour

Bibliography

1. N.M. Atherton, Principles of electron spin resonance, New York, Ellis Horwood/PTR Prentice Hall, (1993)
2. G. Damian & V. Miclăuș, Radicali nitroxidici, Editura Fundației pentru Studii Europene, Cluj-Napoca, (2001)
3. G.R. Buettner & R.P. Mason, Spin-Trapping Methods for Detecting Superoxide and Hydroxyl Free Radicals In Vitro and In Vivo, Critical Reviews of Oxidative Stress and Aging, Advances in Basic Science, Diagnostics and Intervention, I(2): 27-38 (2003)
4. G. Likhtenshtein, J. Yamauchi, S. Nakatsuji, A. I. Smirnov, and R. Tamura, Nitroxides: Applications in Chemistry, Biomedicine and Materials Science, Wiley-VCH (2008)
5. M. Todica, Metode aplicative de rezonanta magnetica nucleara, Presa Universitara Clujeana, 2001 Todica
6. R. Fechete, Nuclear Magnetic Resonance of Elastomers and Biological Tissues, Editura Risoprint, 242 pg, ISBN 978-973-751-775-3 (2008).
7. Radu Fechete, Dan E. Demco, Dumitrita C. Moldovan, Ramona I. Chelcea, Eugen Culea, Rezonanta Magnetica Nucleara: Metode clasice si Moderne, Editura Risoprint, Cluj-Napoca, ISBN 978-973-53-0441-6, pg. 260 (2010).
8. R. Fechete, D. Moldovan, R. Chelcea, Applications of modern NMR techniques to nanocomposite materials and biomaterials, ISBN: 978-973-662-906-8, Editura U.T. PRESS Cluj-Napoca (2013).
9. Robin A. De Graaf, In vivo NMR spectroscopy. Principles and Techniques, John Wiley & Sons, Ltd (2007, Ed. 2), (2019, Ed. 3).

9. Evaluation

Type of activity	9.1 Evaluation criteria[4]	9.2 Evaluation methods[5]	9.3 Percentage in the final grade
9.4. Course	Assessment of knowledge	Written exam (report)	70%
9.5. Seminar/ laboratory	Activity during seminars	Discussions, answers to questions	30%
9.6 Minimum standard for passing			
Correct assessment of methods and models to be used to solve a particular problem. Proper use of computational and experimental techniques and available hardware and software resources.			

10. SDG labels (Sustainable Development Goals)[6]

	○	Sustainable Development Generic Label						
1 FĂRĂ SĂRĂCIE	2 FOAMETE „ZERO"	3 SĂNĂTATE ȘI BUNĂSTARE	4 EDUCAȚIE DE CALITATE	5 EGALITATE DE GEN	6 APĂ CURATĂ ȘI SANITAȚIE	7 ENERGIE CURATĂ ȘI LA PREȚURI ACCESIBILE	8 MUNCĂ DECENTĂ ȘI CREȘTERE ECONOMICĂ	9 INDUSTRIE, INOVAȚIE ȘI INFRASTRUCTURĂ
○	○	○	◉	○	○	○	○	○
10 INEGALITĂȚI REDUSE	11 ORAȘE ȘI COMUNITĂȚI DURABILE	12 CONSUM ȘI PRODUCȚIE RESPONSABILE	13 ACȚIUNE CLIMATICĂ	14 VIAȚA ACVATICĂ	15 VIAȚA TERESTRĂ	16 PACE, JUSTIȚIE ȘI INSTITUȚII EFICIENTE	17 PARTENERIATE PENTRU REALIZAREA OBIECTIVELOR	No label applies
○	○	○	○	○	○	○	○	○

Date of entry: 28.09.2026	Signature of course coordinator	Signature of seminar coordinator
	Prof. dr. Grigore Damian Prof. dr. Mihai Todica Prof. dr. Radu Fechete	Prof. dr. Grigore Damian Prof. dr. Mihai Todica Prof. dr. Radu Fechete
Date of approval in the department: 1.10.2026		Signature of the head of department Prof. dr. Vasile Chiș

[4] The evaluation criteria must directly reflect the learning outcomes targeted at the level of the degree programme respectively at the level of the subject. More specifically, the learning outcomes set out in the expected learning outcomes are assessed.

[5] Both final evaluation methods and ongoing evaluation strategies should be established.

[6] Select a single label which, according to the *Implementation of SDG labels in the academic process*, best matches the subject. If the subject addresses sustainable development in a generic manner (i.e. by presenting/introducing the general framework of sustainable development, etc.), then the Sustainable Development generic label may be applied. If none of the labels describe the subject, select the last option: *"No label applies."*