SYLLABUS

1. Information regarding the program

1.1 Higher education institution	Babeş-Bolyai University
1.2 Faculty	Faculty of Physics
1.3 Department	Doctoral School of Physics
1.4 Field of study	Physics
1.5 Study cycle	Doctorate
1.6 Study program / Qualification	Doctoral training/PhD in Physics

2. Course data

2.1 Name of discipline	Magnetic resonance methods in biomedical research						
2.2 Teacher responsible for lectures	Prof.dr. Grigore Damian, Prof.dr. Mihai Todica, Prof.dr. Radu Fechete						
2.3 Teacher responsible for seminars	Prof.dr. Grigore Damian, Prof.dr. Mihai Todica, Prof.dr. Radu Fechete						
2.4 Year of study	I	**2.5 Semester**	I	**2.6 Type of evaluation**	E	**2.7 Course framework**	DS

3. Estimated total time of teaching activities (hours per semester)

3.1 Hours per week	3	Out of which: 3.2 Lectures	2	3.3 Seminars / Laboratory classes	1
3.4 Total hours in the curriculum	36	Out of which: 3.5 Lectures	24	3.6 Seminars / Laboratory classes	12

Allocation of study time:	**89**
Study supported by textbooks, other course materials, recommended bibliography and personal student notes	34
Additional learning activities in the library, on specialized online platforms and in the field	24
Preparation of seminars/laboratory classes, topics, papers, portfolios and essays	15
Tutoring	12
Examinations	4
Other activities: -	–

3.9 Total individual study hours	89
3.10 Total hours per semester	125
3.11 Number of ECTS credits	10

4. Prerequisites (if necessary)

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

5. Conditions (where applicable)

5.1 Conducting lectures	Course hall, appropriate board, projector, dedicated software, computer
5.2 Conducting seminars/laboratory classes	Course hall, appropriate board, projector, dedicated software, computer network

6. Specific competences acquired

Professional competences	- Acquiring modern concepts and models of molecular dynamics. - Abilities to build molecular dynamic models and prepare input data for numerical simulations. - Ability to use appropriate models for calculating molecular magnetic resonance (NMR, EPR) properties - Correlation of theoretical and simulated data with experimental ones - Communicating complex scientific ideas, the conclusions of experiments or the results of a scientific project. - Ability to obtain and support scientifically argued results; ability to develop scientific papers. - Use of scientific methods and models in narrow or interdisciplinary fields. - Advanced ability to plan and organize. - Operation with the principles of NMR image data processing. Ability to analyze and synthesize data; the ability to model the effect of external factors (RF pulses, gradients) on images. - Use and adaptation of software packages (Processing, JavaScript, Phyton) for data analysis and processing. Use of automated computer systems for processing and extracting data from 2D digital images. - Carrying out data processing experiments and evaluating their results based on existing theoretical models. Multi- and interdisciplinary way of thinking through biomedical applications. -
Transversal competencies	- Modeling and analysis skills in an interdisciplinary context. - Competences in using high performance computing technology. - Carrying out professional tasks efficiently and responsibly, in compliance with the legislation and field-specific deontology. - The application, in the context of compliance with the legislation, of intellectual property rights (including technology transfer), of the product certification methodology, of the principles, norms and values of the code of professional ethics within its own rigorous, efficient and responsible work strategy. - Application of efficient work techniques in multidisciplinary team on various levels hierarchical. Identify roles and responsibilities in a team, apply techniques effective relationships, and work within the team. - Efficient use of information sources and communication and training resources professional, both in Romanian and English. - Demonstrate involvement in scientific activities, such as the development of specialized articles and studies. - To participate in scientific projects, compatible with the requirements of integration in European education and research. -

7. Course objectives (based on the acquired competencies grid)

7.1 The general objective of the discipline	- Learning physical models and advanced experimental methods to calculate magnetic resonance parameters of bio-molecular systems. - Ability to correlate the measured magnetic resonance parameters with the bio-molecular properties.
7.2 Specific objectives	- Acquiring the ability to use advanced computational methods and algorithms in complex simulation projects in the fields of computational spectroscopy, physical chemistry, materials science, imaging and biophysics. - Familiarization of doctoral students with the most used models molecular models and methods in interdisciplinary applications. - Encourage interdisciplinary research. - Learning the principles, methods and computational techniques for calculating different molecular properties. - Efficient use of computational resources for molecular modeling.

8. Content

8.1 Lectures	Teaching methods	Comments
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
5. The principles of two-dimensional magnetic resonance.		2 hours
6. Obtaining spin images.		2 hours
7. FID recording and its analysis by Fourier transformations.		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 Seminars / laboratory classes	Teaching methods	Comments
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 hour
2. Detection and characterization of free radicals in biological systems. Application on the radicals generated in gamma irradiation		2 hour
3. Seminar: Larmor precession, transverse and longitudinal magnetization, relaxation of magnetization. Laboratory: Adjusting the resonance frequency of the 90 degree pulses in the case of a 7 T real RMN spectrometer.		2 hour
4. Seminar: Production of linear magnetic field gradients, anti-Helmholtz coils. Spatial coding using gradient pulses. Laboratory: Adjusting the parameters of the gradient coils in the case of a Real MRI installation and obtaining one-dimensional images on phantom samples.		2 hour
5. 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 hour
6. 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. Miclăuş, *Radicali nitroxidici*, Editura Fundaţiei 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. Aligning the contents of the discipline with the expectations of the epistemic community, representatives, professional associations and standard employers operating in the program field

The content of the discipline is in line with what is studied in other university centers in the country and abroad. In order to adapt to the requirements imposed by the labor market, the content of the discipline was harmonized with the requirements imposed by the specifics of postgraduate education, research institutes and the business environment.

10. Examination

Activity type	10.1 Evaluation criteria	10.2 Evaluation methods	10.3 Weight in the final grade
10.4 Lectures	Assessment of knowledge	Written exam (report)	70%
10.5 Seminars / laboratory classes	Activity during seminars	Discussions, answers to questions	30%
10.6 Minimum performance standard			
Correct assessment of methods and models to be used to solve a particular problem. Proper use of computational techniques and available hardware and software resources.			

Signature of course coordinator	Signature of seminar coordinator
Prof. dr. Grigore Damian	Prof. dr. Grigore Damian
Prof. dr. Mihai Todica	Prof. dr. Mihai Todica
Prof. dr. Radu Fechete	Prof. dr. Radu Fechete

Date	Signature Head of department
21.09.2025	Prof. dr. Vasile Chiș