UNIVERSITY OF RIJEKA – DEPARTMENT OF PHYSICS

GRADUATE STUDY PROGRAMME PHYSICS AND MATHEMATICS

APRIL 2018.

Sveučilište u Rijeci • University of Rijeka

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I. DESCRIPTION OF STUDY PROGRAMME FORM

BASIC INFORMATION	
Title of study programme	**Graduate study programme Physics and Mathematics**
Study programme coordinator	University of Rijeka - Department of Physics
Study programme implementor	Department of Physics of the University of Rijeka (*Study programme coordinator*) Department of Mathematics of the University of Rijeka Faculty of Arts and Sciences of the University of Rijeka
Type of study programme	university
Level of study programme	graduate
Academic/professional degree awarded upon completion of study	Master of education for Physics and Mathematics

1. INTRODUCTION

1.1 Reasons for launching the study programme

The rapid growth of science achievements in the fields of natural sciences and technologies requires a long-term and quality education of experts in these fields. Therefore, we propose the university graduate study programme based on the three-year undergraduate study programme of Physics which has been aimed primarily to provide students with the basic knowledge of physics together with the underlying necessary skills in mathematics. The graduate programme we offer provides the students with more specialized knowledge focused on meeting requirements for teaching profession, which does not preclude by any means a future employment in some other segments of modern society, directed towards development of advanced technologies.

The proposed graduate programme, based on the 45-years of tradition at the University of Rijeka in educational programmes for teachers of natural sciences and mathematics, has been modernized and adapted to suit the requirements of the contemporary educational practice in education of primary and high school teachers of Physics and Mathematics. There is a current shortage of teachers of Physics and Mathematics in all of Europe, including Croatia, with real predictions of even more pronounced shortages in technologically advanced future.

The fundamental knowledge gained during the course of the proposed graduate programme covers:
- the teaching methodology of physics and mathematics with the teaching practice in a real school environment
- the group of pedagogical and psychological courses, the so called teachers module
- a whole series of elective courses associated to the teaching profession and a given specialization,
all of which will make it easier for the future teachers to join the teaching profession and the life-long education in a highly successful and quality way. The full realization of the pedagogical-psychological group of courses, already started during the undergraduate studies within the module for teachers, continues during the graduate studies in full agreement with the curriculum for teaching profession, adopted by the specialist committee of the Faculty of Arts and Sciences of the University of Rijeka and based on the current recommendations for the continuos monitoring and the quality-improvements of the university teaching practice.

1.2 Evaluation of purposefulness in respect to the market needs of public and private sector

The proposed graduate study programme has a potential for securing the sufficient number of physics and mathematics teachers for primary and high schools in the Primorsko-Goranska County and the neighbouring Counties. One expects the shortage of this type of teachers to be even more pronounced in the technologically more advanced future.
In addition, the highly developed logical thinking, independent problem solving and the capability of connecting different

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subjects, with an emphasis on the mathematical component, gained during this study programme, represents a good base for our students to be employed in a variety of jobs in industry and public or private sector, already existing in the work market and with a prospect of an increasing demand in the future.

1.2.1. Connection with the local community (economy, entrepreneurship, civil society)

Currently, there is a great demand in the whole region of our County for the physics and mathematics teachers. The pedagogic-psychological component of this graduate study programme interconnects the area of natural sciences with the area of education, giving rise to the interdisciplinarity of the whole programme and linking the world of science to the local community and, through it, to the civil society.

1.2.2. Compliance with professional association's requirements (recommendations)

The current proposal of the graduate study programme Physics and Mathematic complies in full with the requests, recommendations and strategic documents of several Croatian professional associations, such as the Croatian Physical Society, the Rijeka Society of Physicists and Mathematicians and the Golden Cut Society from Rijeka. Connection of physics with social sciences is known to be a trend in today's world.

1.2.3. Name possible partners outside the higher education system showing interest in the study programme

Currently, all primary and high schools in the Republic of Croatia, having physics and mathematics as subjects in their curricula, have the need and show the real interest for the graduate study programme Physics and Mathematics. In addition, the interest is shown by all private or public businesses employing highly specialized and skilled experts from the field of natural sciences and mathematics.

1.3 Comparability of the study programme with similar programmes of accredited higher education institutions in the Republic of Croatia and the EU (name and explain comparability of the proposed programme with two programmes, whereas at least one of which should be from the EU (provide their web sites))

The proposed study programme is conceptually identical to the graduate programme in Physics and Mathematics at the University of Split. The main part of the proposed study programme consists of methodology courses in physics and mathematics, as well as mathematical and physical courses, with a slightly higher number of mathematical courses. A specific distinctiveness of the proposed study programme is related to the two fundamental courses of Electrodynamics and Quantum mechanics we offer at the graduate level while they are offered at the undergraduate level at the University of Split. Our intention was to follow the recommendations given by the Bologna programme of EU, i.e. to simplify the undergraduate study and to strenghten the graduate studies.

The four-year study programme in Physics and Mathematics at the University of Bath in United Kingdom, which gives the Master of Science (MSc) degree to its students, has a large number of specialized courses in physics and notable fewer courses in mathematics. We believe that our programme is more balanced in terms of number and ratio of courses offered in physics and mathematics and their ECTS values, thus justifying the master degree in both Physics and Mathematics.

The curriculum of the proposed study programme, in connection with the corresponding module of the three-year undergraduate study programme in Physics, is fully commensurable with the licensing procedure for the educational jobs in majority of EU countries. In some countries (Italy, United Kingdom) the pedagogical-psychological component of the study is provided after the professional studies through some specialized pedagogical-psychological educational courses.

The formulation of the propose study programme is based on the curricula of several universities:
Osijek: http://www.fizika.unios.hr/
Split: http://fizika.pmfst.hr/
Zagreb: http://www.phy.hr
Maribor: http://www.fizika.uni-mb.si/
Bochum (Germany): http://physik.ruhr-uni-bochum.de/
Bath (United Kingdom): http://www.bath.ac.uk/physics/
Prag (Cech Republic): http://www.mff.cuni.cz/
Buffalo (USA): http://electron.physics.buffalo.edu/

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1.4. Openness of the study programme towards horizontal and vertical mobility of students within national and international higher education area

All courses of this two-year graduate programme are planned as one-semester courses, enabling a dynamic exchange of content of courses as well as mobility of students within universities in Croatia and EU countries at any stage during the study programme, subject to the completion of all chosen courses.

The direct enrolment to the proposed graduate study programme in Physics and Mathematics is granted to all students having undergraduate degrees from the undergraduate study programme in Physics from the Department of Physics of the University of Rijeka (optional subject Mathematics, teacher training), as well as students graduated in Physics at any university undergraduate study programme with possible requirement of passing exames related to the differences in the curricula.

The students with Master degree can continue their education at related specialized or doctoral studies in Croatia or abroad, subject to requirements of specific higher-education institutions.

During the course of this graduate study programme, students can be redirected to some other graduate study programmes offered by the Department of Physics of the University of Rijeka with requirements of passing some exams related to the differences in the programmes.

1.5. Alignment with the Mission and the Strategy of the University of Rijeka

The proposed study programme is fully compatible with the Mission and the Strategy of the University of Rijeka, while representing at the same time one of the strategic goals of the University, related to the development and growth of natural sciences, IT literacy, development of new technologies, as well as the continual improvement of the educational system at all levels.

The interdisciplinary and multidisciplinary character of the proposed study programme is assured by the consolidation of the existing staff and knowledge from the University of Rijeka and the promotion of the collaboration with the respectable scientific institutions in Croatia. This will contribute to the harmonic and rapid development of the University of Rijeka, but also to the economical and social development of the city of Rijeka and its surrounding region.

1.6 .Institutional strategy for study programmes development

The implementation of the proposed study programme is in accordance with the mission and the strategic goals of the Department of Physics of the University of Rijeka, which insists on the scientific excellence. This goal requires, among other things, the education and training of highly skilled and motivated professional teachers in agreement with requirements of the modern educational practice.

Physics and mathematics represent the foundation of all technical and bio-medical studies, and, accordingly, the prerequisite for the development of industry. As all these activities require an interest for physics and the scientific research to be developed from the primary school ahead, it is critical to develop this interest among kids from the early childhood. The fact that physics is the most selected subject among the elective subjects at the matriculation exams in Croatia clearly shows the increase in awareness among the young generation about the importance and prospect of physics.

The education of students follows the contemporary constructivistic theory of learning and prepare students for implementation of the same educational practice in their future teacher profession. The special attention is paid to the methodology of laboratory and workshop practice in physics and mathematics.

Students showing exceptional affinities and inclination towards the scientific research are introduced to the research projects. Some of them, after completing postgraduate studies and specialization, may find job at the universities or scientific institutes in Croatia or abroad.

1.7. Other important data – according to the coordinator's opinion

The planning and accomplishment of the proposed graduate study programme was realized through the substantial collaboration with the Department of Mathematics of the University of Rijeka and the Faculty of Arts and Sciences of the University of Rijeka. The Department of Physics is having a long lasting collaboration and joined experience in realizing this type of double-degree study programmes.

The proposed graduate study programme has been structured according to recommendations given for Bologna study programmes in EU.

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2. GENERAL PART

2.1. Title of study programme

Graduate study programme Physics and Mathematics

2.1.1. Type of study programme
University programme

2.1.2. Level of study programme
Graduate study programme

2.1.3. Area of study programme (scientific/artistic) – indicate the title
Area-Natural sciences, Fields- Physics and Mathematics Area- Social sciences, Fields- Psychology and Pedagogy

2.2. Study programme coordinator
Department of Physics of the University of Rijeka

2.3. Implementor/s of study programme
Department of Physics of the University of Rijeka Department of Mathematics of the University of Rijeka Faculty of Arts and Sciences of the University of Rijeka

2.4. Duration of study programme (indicate possibilities of part-time study, long distance study)
Two academic years, i.e. four semesters, primarily as full-time, with a possibility of part-time studies.

2.4.1. ECTS credits – minimal number of credits required for completion of study programme
Minimum of 120 ECTS.

2.5. Enrolment requirements and selection procedure
Direct enrolment for all students having undergraduate degree from the undergraduate study programme Physics from the University of Rijeka (optional subject Mathematics – teacher training) and all students graduated in physics at any undergraduate study programme offered by the Croatian Universities, with possible requirement of passing exams in differences in curricula. Selection criteria are based on merits achieved during the undergraduate studies.

2.6. Study programme learning outcomes

2.6.1. Competences which student gains upon completion of study (according to CROQF (HKO): knowledge, skills and competences in a restricted sense –independence and responsibilty)
The general competences gained by students upon completion of studies include: -ability to conduct the teaching duties required for teachers of physics and mathematics in primary and secondary schools in Croatia -community-responsible work in schools which includes the application of pedagogical-psychological skills in both dealing with children and young people and promoting and popularizing natural sciences and mathematics -systematic thinking leading to involvement in a range of jobs in educational sector or jobs based on the application of natural sciences and mathematics -analysis of complex systems in nature or society -knowledge about structure and functioning of physical systems and the ability to apply this knowledge to different areas -application of practical knowledge - ability to work independently or as a member of a team on different projects.

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The more specific competences gained by students upon completion of studies include:
-knowledge and understanding of fundamental physical concepts and their mathematical foundations
-understanding the connection of physical systems with other systems in nature and society
-understanding and solving of basic physical problems at both the qualitative and quantitative level
-development of skills for displaying and interpreting experimental data and connecting the data to the theoretical and mathematical models
-ability to apply the mathematical skills in problem solving
-knowledge of basic computational methods and their application in problem solving
-knowledge and understanding of the influence of physics and mathematics to the development and expansion of science and technology.

2.6.2. Employment possibility (list of possible employers and compliance with professional association's requirements)

After completion of this two-year graduate programme in Physics and Mathematics, the graduated students are fully qualified for jobs of primary or secondary school teachers of physics and mathematics in all schools in Croatia. Employability of graduated students is really high as there is a permanent shortage of this type of job in Croatia with a large teaching load in mathematics in all schools.

The list of possible employers includes: primary and secondary schools, financial institutions (for example banks or the stock exchange), research institutes (for example Institute Ruđer Bošković or Institute of Physics in Zagreb or Science and Technology Park in Rijeka), research and education institutions (University Departments of Physics, Mathematics or Computer Science, all universities or polytechnics having courses of physics and/or mathematics, IT Academy of the University of Rijeka), Oncology Departments and Departments for Nuclear Medicine in hospitals, laboratories in industries and the private sector dealing with the development of new and advanced materials and companies involved in environmental protection or IT.

2.6.3. Possibility of continuation of study on higher level

Masters of education can continue their education at specialist or scientific doctoral studies in Croatia or abroad, subject to the requirements of these institutions. There is also a unique opportunity of doctoral studies in the field of Educational Physics or the Educational Science at some UK or USA Universities, such as University of Maryland in the USA.

2.7. Upon applying for graduate studies list proposer's or other Croatian institution's undergraduate study programmes which enable enrolment to the proposed study programme

Undergraduate study of Physics at the University of Rijeka
Undergraduate study of Physics at the University of Osijek
Undergraduate study of Physics at the University of Split

2.8. Upon application of integrated studies - name reasons for integration of undergraduate and graduate level of study programme

The proposed graduate study programme is not integrated.

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3. PROGRAMME DESCRIPTION

3.1. List of compulsory and elective subjects and/or modules (if existing) with the number of active teaching hours required for their implementation and number of ECTS-credits (appendix: Table 1)

Table 3.1., page 7

3.2. Description of each subject (appendix: Table 3.2.)

Appendix 1, Table 3.2., page 12

3.3. Structure of study programme, dynamic of study and students' obligations

Dynamics of study and student's obligations are regulated by the Rules of studies issued by the University of Rijeka and by the programme of each study course. The whole study programme is divided into four semesters, while every study subject is a one-semester course.

3.3.1. Enrolment requirements for the next semester or trimester (course title)

The enrolment requirements are aligned with the Rules of studies issued by the University of Rijeka. The rules related to the enrolment of a specific course, if existing, are given in the description of that particular course.

3.4. List of courses and/or modules student can choose from other study programmes

Elective mathematical courses in the proposed study programme are the integral part of the graduate programme in Mathematics offered by the Department of Mathematics of the University of Rijeka.

3.5. List of courses and/or modules that can be implemented in a foreign language (specify the language)

All the courses offered by the staff of the Department of Physics of the University of Rijeka can be delivered in English language as consultancies and in agreement with the lecturers.

3.6. Allocated ECTS credits that enable national and international mobility

ECTS credits achieved by students during the study programme (30 ECTS per semester, 120 in total) allow students to change universities and/or study programmes in Croatia or abroad.

3.7. Multidisciplinarity/interdisciplinarity of study programme

The proposed study programme is interdisciplinary and multidisciplinary by its nature and title, as it contains subjects from physics, mathematics and educational sciences and therefore covers the area of natural sciences and social sciences.
The interdisciplinary and multidisciplinary character of the proposed study programme is also assured by the consolidation of the existing staff and knowledge from the University of Rijeka and by the collaboration with scientific organisations in Croatia.

3.8. Mode of study programme completion

The study programme is completed by a final exam consisting of writing and public defence of the Master's Thesis.

3.8.1. Conditions of approval of final work /thesis and/or final/thesis exam application

The final exam can be approved only to students passing all exams required by the study programme Physics and Mathematics and after completion of written Master's Thesis under mentor's supervision.

3.8.2. Composing and furnishing of final work/thesis

The chosen subject of the Master's Thesis should be announced to the mentor at least 30 days from the beginning of the final, fourth semester. Production and features of the Master's Thesis are regulated by the Set of Rules for Master's Thesis production, issued by the Department of Physics.

3.8.3. Final work/thesis assessment procedure and evaluation and defence of final work/thesis

The mentor constantly evaluates the Master's Thesis during its production, while the final assessment is given by the three-member committee during the public defence of Thesis. The whole procedure for the public defence of the Master's Thesis is regulated by the Set of Rules for Master's Thesis production, issued by the Department of Physics.

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TABLE 3.1. : **List of compulsory and elective courses and/or modules with weekly teaching hours required and ECTS credits allocated[1]**

GRADUATE STUDY PROGRAMME PHYSICS AND MATHEMATICS

LIST OF MODULES/COURSES – COMPULSORY COURSES							
Year of study: 1.							
Semester: 1.							
MODULE	**COURSE**		**L**	**E**	**S**	**ECTS**	**STATUS[2]**
	Electrodynamics		3	3	0	7	C
	Demonstration Experiments for Physics Teachers Training		0	0	3	3	C
	Mathematics Education I		2	0	2	6	C
	Metric Spaces		2	2	0	5	C
	Didactics II		2	1	0	4	C
	General pedagogy		2	1	0	4	C

LIST OF MODULES/COURSES – COMPULSORY COURSES							
Year of study: 1.							
Semester: 2.							
MODULE	**COURSE**		**L**	**E**	**S**	**ECTS**	**STATUS**
	Fundamentals of Quantum Mechanics		3	3	0	7	C
	Methods and Strategies in Physics Teaching I		2	0	1	4	C
	Laboratory Experiments for Physics Teachers Training		0	0	3	3	C
	Mathematics Education II		2	0	2	6	C
	Set Theory		2	2	0	7	C
	Elective courses II-FM					4	E

LIST OF MODULES/COURSES – ELECTIVE COURSES II-FM							
Students are required to take 1 course counting for a total of 4 ECTS credits. Course is linked with elective III-FM-A							
Year of study: 1.							
Semester: 2.							
MODULE	**COURSE**		**L**	**E**	**S**	**ECTS**	**STATUS**
	Basic electronics		2	1	1	4	E
	Atomic and Molecular Physics		3	0	1	4	E

L – Lectures, E – Exercises, S – Seminars

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[1] The total number of teaching hours for a particular course in semester is obtained multiplying weekly teaching hours by 15.
[2] **IMPORTANT:** Insert **C** for compulsory course or **E** for elective course.

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LIST OF MODULES/COURSES – COMPULSORY COURSES							
Year of study: 2.							
Semester: 3.							
MODULE	**COURSE**		**L**	**E**	**S**	**ECTS**	**STATUS**[3]
	Methods and Strategies in Physics Teaching II		2	0	1	4	C
	History of Physics		1	0	1	2	C
	Methodical practice in mathematics I		0	4	0	4	C
	Algebraic Structures		2	2	0	7	C
	Elective courses III-FM-A					5	E
	Elective courses III-FM-B					2	E
	Elective courses III-FM-C					6	E

LIST OF MODULES/COURSES – ELECTIVE COURSES III-FM-A							
Students are required to take 1 course counting for a total of 5 ECTS credits. Course is linked with elective II-FM							
Year of study: 2.							
Semester: 3.							
MODULE	**COURSE**		**L**	**E**	**S**	**ECTS**	**STATUS**
	Electronics laboratory		0	0	4	5	E
	Structure of Matter Lab		0	0	4	5	E
LIST OF MODULES/COURSES – ELECTIVE COURSES III-FM-B							
Students are required to take at least 1 course counting for a total of 2 or more ECTS credits.							
Year of study: 2.							
Semester: 3.							
MODULE	**COURSE**		**L**	**E**	**S**	**ECTS**	**STATUS**
	Conceptual Physics		1	0	1	2	E
	Interdisciplinary Subjects in Physics Teaching		1	0	1	2	E
	Science Popularization		1	0	1	2	E
	Computers in Physics Teaching		1	0	1	2	E

L – Lectures, E – Exercises, S – Seminars

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[3] **IMPORTANT:** Insert **C** for compulsory course or **E** for elective course.

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LIST OF MODULES/COURSES – ELECTIVE COURSES III-FM-C							
Students are required to take at least 1 course counting for a total of 6 or more ECTS credits.							
Year of study: 2.							
Semester: 3.							
MODULE	**COURSE**		**L**	**E**	**S**	**ECTS**	**STATUS**
	Mathematics Seminars I		0	0	2	3	E
	Geometry models		2	2	0	5	E
	Linear Programming		2	2	0	6	E
	Algebra I		2	2	0	6	E
	Measure and Integral		2	2	0	6	E
	Number theory		2	2	0	6	E
	Graph theory		2	1	1	6	E
	Vector Spaces I		2	2	0	6	E
	Finite geometries		2	0	1	6	E
	Permutation groups		2	0	1	7	E
	Introduction to design theory		2	1	1	6	E

LIST OF MODULES/COURSES – COMPULSORY COURSES							
Year of study: 2.							
Semester: 4.							
MODULE	**COURSE**		**L**	**E**	**S**	**ECTS**	**STATUS**[4]
	Teaching Practice in Physics		0	3	0	4	C
	Methodical Practice in Mathematics II		0	4	0	4	C
	Introduction to Probability and Mathematical Statistics		2	3	0	6	C
	Introduction to differential geometry		3	2	0	7	C
	Graduate Thesis					5	C
	Elective courses IV-FM-A or IV-FM-B					4	E

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[4] **IMPORTANT:** Insert **C** for compulsory course or **E** for elective course.

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LIST OF MODULES/COURSES – ELECTIVE COURSES IV-FM-A

Students are required to take at least 1 course from either IV-FM-A or IV-FM-B, counting for a total of 4 or more ECTS credits.

Year of study: 2.

Semester: 4.

MODULE	COURSE		L	E	S	ECTS	STATUS
	Fundamentals of Astronomy and Astrophysics		2	1	1	5	E
	Biophysics		2	0	2	5	E
	Experimental Methods in Physics		2	1	1	5	E
	Solid State Physics		2	1	1	5	E
	Elementary Particle Physics		3	0	1	5	E

LIST OF MODULES/COURSES – ELECTIVE COURSES IV-FM-B

Students are required to take at least 1 course from either IV-FM-A or IV-FM-B, counting for a total of 4 or more ECTS credits.

Year of study: 2.

Semester: 4.

MODULE	COURSE		L	E	S	ECTS	STATUS[5]
	History of Mathematics		1	0	2	3	E
	Mathematics Seminars II		0	0	2	3	E
	Topics in contemporary mathematics		1	0	1	3	E
	Additional Mathematics		2	2	0	4	E
	Selected lectures from teaching mathematics		2	2	0	4	E
	Mathematics Seminars III		0	0	2	4	E
	Discrete Mathematics		2	2	0	5	E
	Geometry		2	2	0	5	E
	Vector Spaces II		2	2	0	6	E
	Algebra II		2	2	0	6	E
	Partial differential equations		2	2	0	6	E
	Harmonic analysis		2	0	1	6	E
	Coding theory and cryptography		2	0	1	6	E
	Probability theory		2	2	0	6	E

L – Lectures, E – Exercises, S – Seminars

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[5] **IMPORTANT:** Insert **C** for compulsory course or **E** for elective course.