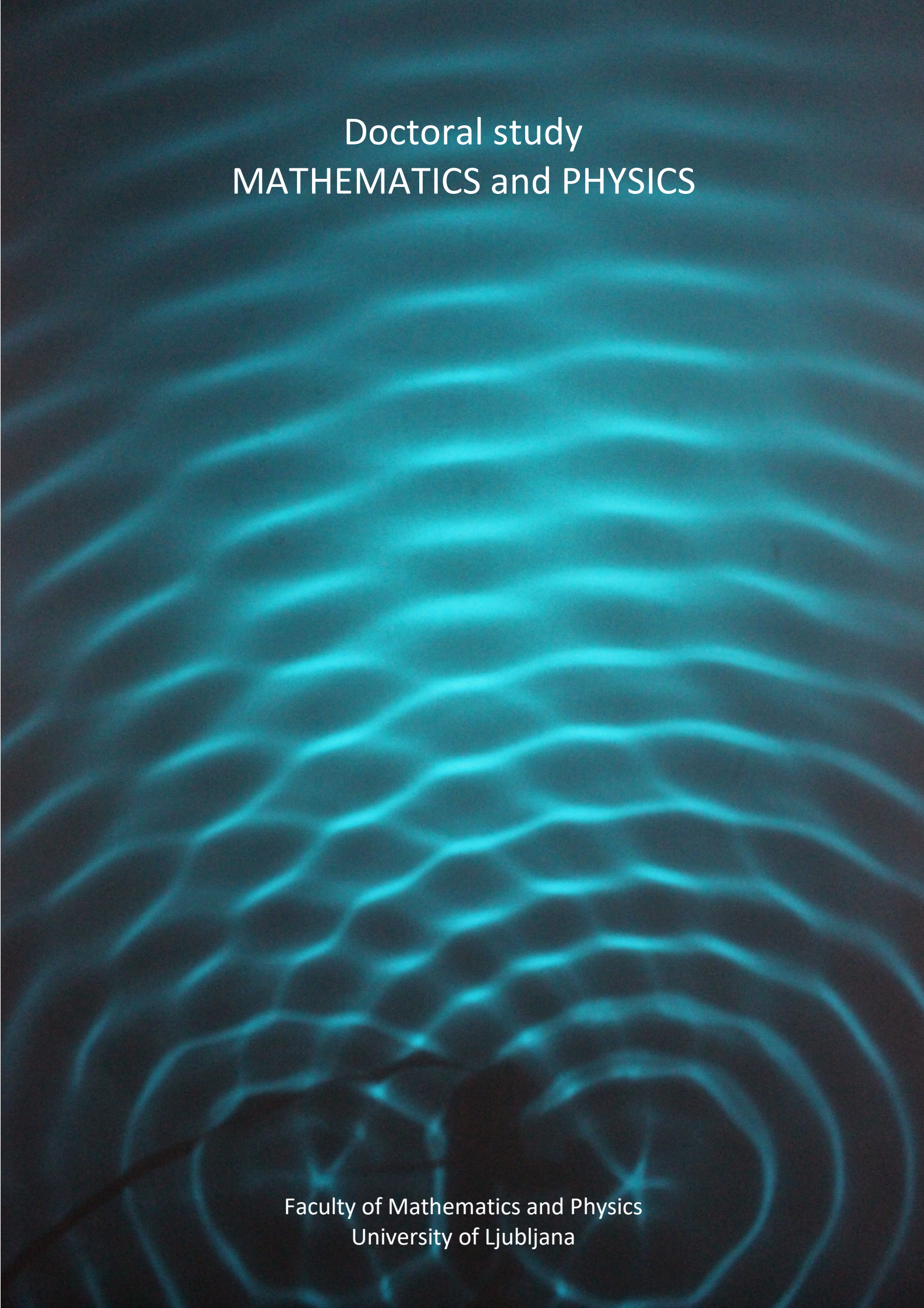

Doctoral study
MATHEMATICS and PHYSICS

Faculty of Mathematics and Physics
University of Ljubljana

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HANDBOOK

Doctoral study programme

MATHEMATICS AND PHYSICS

Ljubljana, February 2019

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0. INTRODUCTION

Mathematics and physics have been studied at the University of Ljubljana since the University was first established in 1919. The original study programmes, which were the first on Slovene territory, were intended for future teachers. Later, the programmes broadened to accommodate physics, astronomy, meteorology and pedagogical physics, and the study of mathematics and pedagogical mathematics. The programmes have since been reorganised several times, alongside more general reorganisation within the University. The study of theoretical physics and mathematics originally took place at the Faculty of Philosophy, with the study of experimental physics being carried out at the Technical Faculty and the Medical Faculty. Later, all mathematics and physics programmes were accommodated within the Faculty of Natural Sciences and Mathematics, and then from 1960 to 1995 at the Faculty of Natural Sciences and Technology. Finally, in 1995, the current Faculty of Mathematics and Physics (FMF) was founded. It has two departments: the Department of Mathematics, and the Department of Physics. The address of the Faculty is: Jadranska 19, 1111 Ljubljana (phone +386 1 4766500).
The second half of the 20th century was a period of very rapid development in both mathematics and physics. Many new fields were introduced, while older ones underwent intense specialisation. All this is reflected in the research activities of Slovene mathematicians and physicists, as well as in the doctoral programme in Mathematics and Physics, which is designed according to the guidelines of the Bologna Accord.
The Department of Physics and the Department of Mathematics are the two largest Slovene schools in their respective fields. Both departments have extensive scientific connections with mathematicians and physicists all over the world, and many FMF members have spent considerable time abroad. The results of the research of FMF members are published in the top international mathematics and physics journals. The foundation for the doctoral programme in Mathematics and Physics is research in the fields of mathematics and physics, with the collaboration of internationally recognised Slovene and foreign experts, who can serve as advisers for students. In accordance with recommendations of the European University Association (EUA), the programme includes possibilities for international student exchange. The publication of at least one scientific paper as a result of the doctoral research is required.

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1. DESCRIPTION OF THE PROGRAMME

The doctoral study programme in Mathematics and Physics is a third-cycle programme within the Bologna framework for higher education. From the academic year 2019/20 onwards, the programme will last for 4 years and comprise 240 credit points. The programme combines taught study, which accounts for 60 credit points, with individual research and the preparation and defence of the doctoral dissertation, which together account for the remaining 180 credit points. The programme is made up of two subprogrammes: one in Mathematics and one in Physics. The Physics subprogramme is divided into four separate modules: Physics, Physics Education, Meteorology, and Nuclear Physics. The Mathematics subprogramme has two modules: Mathematics and Mathematical Education.
The study requirements of the programme have been designed in compliance with the Higher Education Act and with the Criteria for the Accreditation of Institutions and Study Programmes in Higher Education, adopted by the Higher Education Council of the Republic of Slovenia. They are accredited according to the European Credit Transfer System (ECTS), which makes it possible for parts of the programme to be completed via international exchange with other universities that use the ECTS system.
Upon successful completion of the programme, the candidate is awarded the title Doctor of Science.

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2. FUNDAMENTAL OBJECTIVES OF THE PROGRAMME and COMPETENCIES

The main objective of the study programme in Mathematics and Physics is to produce highly qualified researchers and experts capable of conducting independent research and development in the fields of physics, astrophysics, nuclear physics, meteorology, mathematics, and mathematical and physics education, at a level comparable to and competitive with current top-quality research pursued in the most advanced parts of the world. In this regard, independent research towards the doctoral thesis, which is the main component of the doctoral study programme, develops in-depth knowledge in the area of immediate specialization. This is supplemented by the organized part of the study programme, which develops the broader knowledge that is

indispensable for any young researcher to be able to efficiently respond to rapid development and change in modern science, or for them to participate in larger interdisciplinary research teams.
The organized part of study in the Physics subprogramme is designed so that the student must select one subject from a collection of subjects (group A) that are relevant to the selected module and which cover the broad research field of the doctorate. These courses offer deeper insights into the general principles of physics, and provide a sound and broad knowledge base for independent research. The remaining subjects are completely optional (group B) and are intended for narrower specialization in the area of the candidate's doctoral research.
The Mathematics subprogramme is intended mainly for mathematicians who have completed the second cycle of a Bologna degree (Master's degree) and is aimed at those who wish to pursue independent research or industrial development work in the field of mathematics or mathematical education. The main objective of the Mathematics subprogramme is the training of highly qualified experts in the fields of mathematics and mathematical education. In addition to deepening their broader knowledge of mathematics or mathematical education, students will develop their capacity for independent and critical scientific thinking and will be capable of carrying out independent research and creating new knowledge in their field of research.
The above characteristics mean that students who complete the study programme will be qualified to work successfully in a wide range of research and applied disciplines in the fields of mathematics, natural and engineering sciences, medicine, economics, computer science, and in educational institutions and research institutes, etc.

General competencies acquired with the programme:

- Capacity for abstraction and problem analysis
- Gathering, critical evaluation and synthesis of data, measurements and solutions
- Identification of data needed for obtaining new knowledge
- Forming new knowledge on the basis of existing theories and available data
- Use of knowledge in practice (especially in modern technologies)
- Capacity for interdisciplinary integration of scientific knowledge
- Capacity for both autonomous research and development, and for working in an (international) group
- Communicating scientific knowledge to the general public
- Ability to use modern research methods and procedures
- Ability to critically evaluate and present one’s own results
- Capacity for further independent education, research and following of the literature

Subject-specific competencies:

- In-depth understanding of the physical laws of nature
- Combining the basic laws of nature and observable properties of the world
- Ability to creatively identify physical problems and analyse them
- Capacity for the mathematical formulation of physical problems
- Deduction of the physical basis of practical problems
- Ability to model problems
- Advanced physical experimental skills
- Critical evaluation of the results of measurements and their use in the construction of models
- Understanding the principles of operation of technical devices on the basis of fundamental laws
- Presentation of physical methods and results adapted to the target public
- Ability to convey knowledge of physics
- Thorough understanding of the results of research in the field of interest
- Ability to understand the most advanced mathematical problems and proofs
- Independence in research
- Capacity for abstraction of practical problems
- Ability to follow and use scientific mathematical literature
- Ability to use various modern mathematical methods for problem solving
- Capacity for critical and independent work and for consultation in the field of mathematical and physics education.

3. INTERNATIONAL COOPERATION

FMF participates in the following professional organizations:

- AAPT (American Association of Physics Teachers)
- AGU (American Geophysical Union)
- AMPERE (Association for Microwave Power in Europe for Research and Education)
- AMS (American Meteorological Society)
- AMS (The American Mathematical Society)
- APS (American Physical Society)
- Biophysical Society
- EAS (European Astronomical Society)
- ECMI (The European Consortium for Mathematics in Industry)
- EMS (The European Mathematical Society)
- ENEN (European Nuclear Education Network)
- EPS (European physical society)
- FuseNet Association
- HOPE (Horizons in Physics Education)
- ILCS (The International Liquid Crystal Society)
- IOP (Institute of Physics)
- MAA (The Mathematical Association of America)
- SIAM (The Society for Industrial and Applied Mathematics)

FMF collaborates with numerous academic and research institutions. For example:

- CERN (Conseil Européen pour la Recherche Nucléaire)
- ETH (Eidgenössische Technische Hochschule Zürich)
- LANL (Los Alamos National Laboratory)
- Ludwig-Maximilians-Universität München
- MIT (Massachusetts Institute of Technology)
- University of Oxford
- Stanford University
- University of Cambridge
- University of California
- Weizmann institute, Izrael

FMF international cooperation:
http://www.fmf.uni-lj.si/si/raziskave/

The mobility of students and teachers is supported by the Erasmus programme:
http://www.fmf.uni-lj.si/si/studenti-matematike/erasmus/bilateralne-pogodbe/
http://www.fmf.uni-lj.si/si/studenti-fizike/erasmus/bilateralne-pogodbe/

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4. RESEARCH PROGRAMMES

Research projects:
http://www.imfm.si/raziskave-in-projekti/raziskovalni-projekti
https://www.fmf.uni-lj.si/si/raziskave/fizika/

Internationally renowned research projects:
http://sicris.izum.si/search/org.aspx?opt=4&id=767

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5. CURRICULUM

Organized forms of study (60 ECTS)

a) Subprogramme in Physics
- courses (30 ECTS): (compulsory module course, selective courses)
- other organized activities (30 ECTS): (individual study, preparation and presentation of the dissertation topic, compulsory seminar)

b) Subprogramme in Mathematics
- courses (30 ECTS) (5 out of 9 electives)
- other organized activities (30 ECTS): (Individual study 1 and 2, Pre-doctoral exam, active participation in research seminars)

Research, doctoral dissertation and defence (180 ECTS)

a) Subprogramme in Physics

The research work is concluded with a dissertation and its defence, and with the publication of at least one scientific article from the field of the dissertation in one of the journals from groups I - III, as defined in the FMF Interpretation of the *Criteria for Election of University Teachers, Researchers and Research Associates.* The candidate should be the first author of the publication. If this is not possible, the supervisor should provide a declaration that the contribution of the candidate to the publication is important.

b) Subprogramme in Mathematics

The research work is concluded with a dissertation and its defence, and with a publication of at least one scientific article from the field of the dissertation in one of the journals from group I - III, as defined in the FMF Interpretation of the *Criteria for Election of University Teachers, Researchers and Research Associates.* The candidate should be the first author of the publication. If this is not possible, the supervisor should provide a declaration that the contribution of the candidate to the publication is important.

A detailed syllabus:

a) Subprogramme in Physics

ECTS		
12	Compulsory course of the module	Organized forms of study 60 ECTS
9	Individual study	
15	Preparation and presentation of dissertation theme	
6	Compulsory seminar	
18	Elective courses	
180	Individual research, preparation of doctoral dissertation and defence	
240		

Compulsory courses (group A) with lecturers (regarding modules):
- Selected Topics in Contemporary Physics (Prof. dr. Boštjan Golob)
- Selected Topics in Physics Education Research (Prof. dr. Gorazd Planinšič)
- Selected Topics in Atmospheric Sciences (Prof. dr. Nedjeljka Žagar)
- Selected Topics in Reactor Physics and Engineering (Prof. dr. Iztok Tiselj)

Elective courses (group B) with lecturers:
- Specialized Seminar on Theoretical Physics (Prof. dr. Primož Ziherl)
- Specialized Seminar on Experimental Physics (Prof. dr. Denis Arčon)
- Specialized Seminar on Physics Education Research (Prof. dr. Gorazd Planinšič)
- Specialized Seminar in Atmospheric Sciences (Asst. prof. dr. Gregor Skok)
- Specialized Seminar on Nuclear Physics and Engineering (Asst. prof. dr. Luka Snoj)
- Summer schools and other organized education (3 or 6 ECTS),

- Courses on other UL doctoral programmes or at other universities (up to 12 ECTS).

The choice of courses must be supported by the supervisor and approved by the FMF Department of Physics Study Board.

Syllabus by years:

1st year	ECTS	share (%)
Compulsory module course	12	20
Preparation of dissertation theme	15	25
Compulsory seminar	6	10
Individual study	9	15
Elective courses	6	10
Individual research	12	20
	60	100

2nd year

Elective courses	12	20
Individual research	48	80
	60	100

3rd year

Individual research	60	100
	60	100

4th year

Individual research	54	90
Dissertation preparation and defence	6	10
	60	100

b) Subprogramme in Mathematics

ECTS		
30	5 elective courses (6 ECTS each)	Organized forms of study 60 ECTS
12	Individual study (2 x 6 ECTS)	
12	Seminar / disposition (2 x 6 ECTS)	
6	Predoctoral exam (6 ETCS)	
180	Individual research, doctoral dissertation preparation and defence	
240		

Syllabus by years:

1st year	ECTS	share (%)
Elective courses (3 x 6 ects)	18	30
Seminar 1	6	10
Predoctoral exam	6	10
Individual study	6	10
Individual research	24	40
	60	100

2nd year

Elective courses (2 x 6 ECTS)	12	20
Seminar 2	6	10
Individual study	6	10
Individual research	36	60
	60	100

3rd year

Individual research	60	100
	60	100

4th year

Individual research	54	90
Dissertation preparation and defence	6	10
	60	100

6. ENROLMENT REQUIREMENTS and SELECTION CRITERIA IN CASE OF RESTRICTED ENROLMENT

Conditions for enrolment:
Candidates can enrol in the doctoral study programme if they have successfully completed:

- A second-cycle (i.e., master's) study programme.
- A university-level degree programme accredited before 11.6.2004.
- A study programme for specialisation following completion of a profession-oriented higher education programme. In this case, the relevant doctoral studies board (either mathematics or physics) will determine any additional study requirements that need to be fulfilled. These requirements may be tailored to the individual, or they may involve between 30 and 60 ECTS points of additional courses to study.
- A profession-oriented study programme that is either regulated by directives of the European Union or is a master's programme, and which carries at least 300 ECTS credit points.
- A Master's level study programme or a study programme for specialization, having previously completed another University-level degree programme. In accordance with the law, such candidates may request up to 60 ECTS credit points in recognition of their previous education.

Enrolment in the doctoral study programme in Mathematics and Physics is open also to graduates of foreign universities. In accordance with the Statutes of the University of Ljubljana, the equivalence of previous education acquired abroad is established as part of the process of recognition of foreign education for the continuation of education at University of Ljubljana.

Criteria for selection in case of restricted enrolment:
In the case of a size-limited enrolment process, the selection of the candidates will be based on:

- The average mark in previous studies (15%)
- The mark for the diploma or master's work (5%)

- The score achieved in a written selection exam (80%) in physics or mathematics. The score from this exam can be partially (up to 40%) be replaced by the candidate's research and professional achievements in the area of the study programme.

Note: By the end of the application deadline, the candidate must have an agreement with a higher education teacher or researcher to act as mentor / co-mentor for their doctoral studies. The written consent of the mentor / co-mentor must then be submitted at the time of enrolment, together with a short high-level outline of the planned research topic of the doctorate.

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7. CRITERIA FOR KNOWLEDGE RECOGNITION

A student can be awarded credit for knowledge acquired in different forms of previous education that corresponds in content to courses in the study programme. Decisions concerning the recognition of such knowledge are made by the Department of Physics and Department of Mathematics Study Boards at FMF, on the basis of the student's written application with attached testimonials and other documents confirming successful acquisition of such knowledge and its content.
In awarding credit for an individual course, the Study Board will use the following criteria:
- comparability of the scope of previous education with the scope of the course for which credit is awarded,
- correspondence of the content of previous education to the content of the course for which credit is awarded.

In cases in which the Study Board determines that the acquired knowledge can be recognised, it is accredited with the number of ECTS points attached to the corresponding courses.

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8. ASSESSMENT

The assessment methods follow the Statutes of the University of Ljubljana, and are listed in the curricula.

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9. REQUIREMENTS FOR PROGRESSION

Physics Subprogramme:

For enrolment in the second year of study, students must make a successful presentation of the theme of doctoral dissertation and they must collect a total of at least 48 ECTS from organized forms of study. For enrolment into the third year, the student must collect at least 90 ECTS, of which 60 are required to be from organized forms of study (the compulsory course for the selected module, elective courses, courses from external study programmes, international summer schools, etcetera). In addition, prior to enrolment in the third year of study, the opinion of Commission for monitoring the doctoral student (KSDŠ) that the dissertation topic is suitable for a doctoral dissertation must be confirmed by the Senate of the Faculty (UL FMF). For enrolment into the fourth year of study, the student must meet all study requirements for the first three years, and obtain approval of the subject of the doctoral dissertation from the Senate of UL.

Mathematics Subprogramme :

For enrolment in the second year of study, students must obtain at least 48 ECTS, of which 6 must be from the predoctoral exam, and another 24 from other organized forms of study (elective courses, seminar, individual studies, etcetera) during the first year. For enrolment into the third year, the student must collect at least 90 ECTS, of which 60 have to be from organized forms of study (as above, but including the predoctoral exam). In addition, prior to enrolment in the third year of study, the opinion of Commission for monitoring the doctoral student (KSDŠ) that the dissertation topic is suitable for a doctoral dissertation must be confirmed by the

Senate of the Faculty (UL FMF). For enrolment into the fourth year of study, the student must meet all study requirements for the first three years, and obtain approval of the subject of the doctoral dissertation from the Senate of UL.

Re-enrolment into the same year of study must be approved by the Department of Physics Study Board or by the Department of Mathematics Study Board at FMF.

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10. REQUIREMENTS FOR TRANSFERS

Transfer to the doctoral (third-cycle) programme in Mathematics and Physics is possible:

- From other doctoral (third-cycle) programmes of UL. The candidate must fulfil the requirements for enrolment in the doctoral (third-cycle) programme in Mathematics and Physics. On the basis of credit points awarded for exams taken in the previous study programme, the FMF Study Board may require a candidate to take bridging exams (corresponding to up to 60 ECTS points) and decide in which year of study he/she may enrol.
- Under the same conditions as in the previous paragraph, transfer is possible also from comparable programmes at other universities if the candidate meets the requirements for enrolment in the doctoral (third-cycle) programme in Mathematics and Physics.

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11. MODE OF STUDY

For official purposes, the mode of study for doctoral degrees is classified as ``izredni'' (part-time).

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12. REQUIREMENTS FOR THE COMPLETION OF STUDY

The requirements for completion of study and acquisition of the title Doctor of Science are that the candidate successfully meets all study requirements laid down in the programme and successfully defends the doctoral dissertation, amounting to a total of 240 ECTS. That is the student must fulfil all requirements for organised study (amounting to 60 ECTS), as well as for individual research work including the preparation and defence of the doctoral dissertation (amounting to 180 ECTS). The candidate must also publish or have accepted for publication at least one scientific article from the field of the dissertation in one of the journals from group I - III, as defined in the FMF Interpretation of the *Criteria for Election of University Teachers, Researchers and Research Associates, as approved at the UL Senate on 22.11.2016*. If it is not possible for the candidate to be the first author of the publication, the mentor should provide written confirmation of the significance of the candidate's contribution. The research article must be published or accepted for publication prior to the doctoral dissertation being submitted for evaluation. For the student to complete the doctorate, the dissertation and its defence must receive positive evaluations from the examining committee.

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13. COURSES and ADVISORS

Physics	**Mathematics**
Selected Topics in Contemporary Physics	Topics in Analysis
Selected Topics in Physics Education Research	Topics in Algebra
Selected Topics in Atmospheric Sciences	Topics in Topology
Selected Topics in Reactor Physics and Engineering	Topics in Geometry

Specialized Seminar on Theoretical Physics

Specialized Seminar on Experimental Physics

Specialized Seminar on Physics Education Research

Specialized Seminar in Atmospheric Sciences

Specialized Seminar on Nuclear Physics and Engineering

Topics in Discrete Mathematics

Topics in Numerical Mathematics

Topics in Computational Mathematics

Topics in Probability and Statistics

Topics in Financial Mathematics

Possible advisors

Web presentations:
ENG: http://www.fmf.uni-lj.si/studij-matematike/fmf/EngZ.pdf
SLO: http://www.fmf.uni-lj.si/studij-matematike/fmf/SloZ.pdf