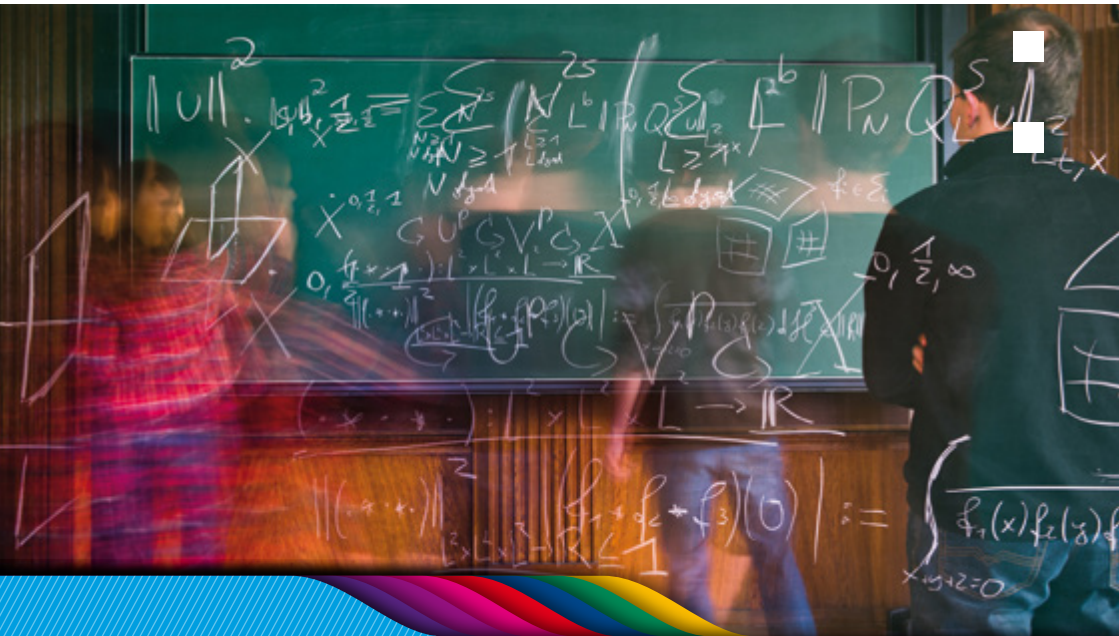universität**bonn**

Master of Science Mathematics

MATHEMATICS

From Studying to Research in Bonn

Greetings

If you ask any mathematician between San Francisco and Tokyo, where in Germany to study mathematics, the answer will likely be Bonn. What can I add to this ?!

Bonn offers – and has done so for decades – an excellent education in mathematics. World-famous researchers teach an enthusiastic group of students.

There is a Bachelor's program for a solid introduction to a variety of fields. And there is an international Master's program, ambitious and research oriented, in which the language of instruction is English. Its advanced lecture courses and seminars leads you to the forefront of knowledge. And perhaps to the start of a PhD thesis.

So why not apply ?

C.-F. Bödigheimer, June 15th, 2012
Chairman of the Mathematics Department

Table of Contents

According to its mission as a research university, all courses of study teach fundamental scientific research methods, even in the 6-semester Bachelor's programs. This gives students optimal preparation for the large variety of 4-semester Master's programs that build on the Bachelor's programs. For every Bachelor's program, you will find at least one, often several, related research-oriented Master's programs at the University of Bonn. Exceptionally qualified students can complete their studies with a PhD, e.g. at the Bonn International Graduate Schools. The high percentage of foreign students and visiting researchers ensures an international flair and the many international companies and organizations located in the city also provide a host of job opportunities and a wide range of internships.

The University of Bonn also benefits from the town and region in which it is located. Bonn started to make its mark on the international stage in the 1950s when it had just become the capital of West Germany. Its popular museums and concert halls are by no means typical of a medium-sized city. Since the government and parliament moved to Berlin in the 1990s, Bonn has continued to pursue its goal of becoming an international center for research and sustainable development with as much dedication as ever. Today, the name 'Bonn' is known throughout the world, not least because over the years, many UN institutions and nearly 200 international institutes and organizations have moved to the city on the Rhine: Bonn is today more international than ever.

Bonn is also a prospering business center and the heart of a pulsating science region with a number of high-profile non-university research institutions – something many of you may be able to turn to your advantage during your stay here. Many of the companies and institutions located here not only offer job opportunities, but they also cooperate with the University of Bonn itself in many areas.

When you start looking around you will soon realize that Bonn has a lot more to offer than just beautiful surroundings criss-crossed by cycle routes and hiking paths. Bonn offers the internationally acclaimed Museum Mile, vibrant theater and non-mainstream cinema as well as an upbeat music scene and (political) cabaret. Students make up almost 10% of the city's population and their needs and interests are catered to. You will find trendy cafés and pubs, international cuisine and outdoor beer and wine gardens in this "northernmost Italian city", as the locals say. And on top of this, the Rhineland is a good place to live, centrally located in Europe, with many cultural and tourist highlights just a train-ride away.

1. Studying at the University of Bonn

An excellent reputation, around 30,000 students and nearly 200 years of history: Rheinische Friedrich-Wilhelms-Universität Bonn is one of the leading universities in Germany. Its more than 500 professors and approximately 3,800 academic personnel define a special academic profile, which is characterized by a strong research orientation in its teaching. The university has thus produced numerous award-winning scientists, including two Nobel laureates (Wolfgang Paul in Physics and Reinhard Selten in Economics). Furthermore the only German Field's Medalist, Gerd Faltings, works at the Max Planck Institute for Mathematics in Bonn. The university is a particularly attractive destination for international researchers and students. Around 3,700 international students from more than 135 countries currently enjoy the academic and social life of the university. The University of Bonn cooperates with some 70 partner universities in Europe, America, Asia and Australia.

The University of Bonn has seven faculties (Catholic Theology, Protestant Theology, Law and Economics, Medicine, Arts, Mathematics and Natural Sciences, Agriculture), as well as a teacher training center. The faculties offer a total of 80 Bachelor's and 60 Master's programs. In addition, students can choose from a large variety of secondary subjects. Many of the programs are international and some of them are taught in English. This diversity of subjects offers outstanding opportunities for interdisciplinary work.

2. Mathematics in Bonn

Bonn is one of Europe's leading locations for mathematical research. It is home to Germany's only government-funded Cluster of Excellence in mathematics, the Hausdorff Center for Mathematics.

2.1 HISTORY

Bonn has a long scientific tradition in mathematics, going back to the 19th century. The early history of mathematicians working in Bonn is most notably illustrated by the years 1866–68, when three major mathematicians of their time collaborated in Bonn: *Julius Plücker* (geometer and known for his work on the physics of vacuum tubes), *Rudolf Lipschitz* (famous not only for his continuity criterion) and the then 17-year old *Felix Klein* (later to become a pioneer in geometry and function theory). Plücker died in 1868 and Klein started his career in 1872 as professor in Erlangen, Munich, Leipzig and finally Göttingen, while Lipschitz continued to work in Bonn.

Felix Hausdorff (1868–1942)

In the first half of the 20th century, *Otto Toeplitz* (working on functional analysis and the history of mathematics) and *Felix Hausdorff* (one of the founders of modern topology) worked in Bonn. Both were outstanding and internationally highly esteemed mathematicians and both were Jewish. During the national socialist regime, they were forced to retire. Hausdorff, his wife and her sister committed suicide in 1942 shortly before their imminent deportation to a concentration camp.

After the war, Bonn expanded into Germany's largest center for mathematics. *Friedrich Hirzebruch* (topologist and algebraic geometer), who in 1980 also founded Germany's first Max Planck Institute for Mathematics in Bonn, played a major role in this development. In 2006, the so-called Excellence Initiative awarded Bonn with Germany's only Cluster of Excellence in mathematics, named *Hausdorff Center for Mathematics* (HCM) in honor of Felix Hausdorff. HCM unites more than 50 professors in mathematics and economics from the university and the Max Planck Institute, among whom there are numerous holders of Leibniz Prizes, Max Planck Research Awards and the only German Field's medalist, *Gerd Faltings* (arithmetic algebraic geometer).

2.2 PROFILE

Mathematical research in Bonn is characterized by a particularly broad research spectrum. All important areas of mathematics are represented here: from the classical core areas in pure and applied mathematics to mathematical modeling, numerical simulation and the transfer of mathematics into technological applications. In national and international rankings, Bonn occupies a leading rank in mathematical research and teaching within Germany.

The Department of Mathematics consists of four institutes for pure, applied, numerical and discrete mathematics, with a total of 45 tenured or non-tenured professors. The Max Planck Institute in Mathematics has strong ties to the University of Bonn and collaborates actively with the Department. The research activities have as a common roof the Hausdorff Center for Mathematics (HCM). HCM includes the Bonn International Graduate School (BIGS, a graduate school for about 130 PhD students) and the Hausdorff Research Institute for Mathematics (HIM) organizing trimester programs for guest researchers from all over the world.

The following pages give examples of research topics (mostly from HCM Research Areas), one for each possible specialization in our Master's program (cf. Section 3.2).

2.3 AREAS OF RESEARCH

A Research in

Algebra, Number Theory and Logic

Research in Bonn covers a broad spectrum of topics in Algebra and Algebraic Geometry, Number Theory and Mathematical Logic.

Areas of particular focus include

- **Algebra and Representation Theory**
- **Arithmetic Algebraic Geometry**
- **Complex Geometry**
- **Mathematical Logic**

Example: "Analytic, algebraic and combinatorial aspects of moduli theory"

Picture: Some of the Bonn Algebraists, thinking and discussing mathematics.

The HCM Research Area "Analytic, algebraic and combinatorial aspects of moduli theory" brings together researchers working with a broad variety of techniques on a number of fundamental questions in moduli space theory. Moduli spaces of complex curves or Riemann surfaces, of abelian varieties, of vector bundles and of representations of algebras are studied from algebraic and differential geometric as well as from arithmetic and topological points of view.

In many occasions, moduli spaces can be used to build bridges between seemingly different areas of mathematics. For example, the moduli spaces of representations of preprojective algebras are intimately linked with Lie theory, quantum groups and the categorification of cluster algebras.

B Research in

Analysis and Partial Differential Equations

Our research covers many diverse aspects of Analysis and its applications in the natural sciences and ranges from pure mathematics over applied mathematics to numerical simulation.

- **Calculus of Variations**
- **Global Analysis**
- **Harmonic Analysis**
- **Mathematical Aspects of Materials Science**
- **Mathematical Physics**
- **Partial Differential Equations**
- **Variational Methods in Image Processing**

Example: "Shape, Pattern and Partial Differential Equations"

Picture: Crumpled paper sheets display complex structures spanning many different length scales. A macroscopic compression is mesoscopically realized via "origami maps", on a finer scale one sees single folds with optimal energy.
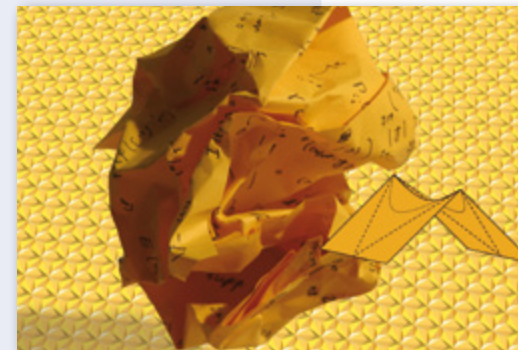
The interplay of the concepts of shape (interfaces in materials or geometric contours in images) and pattern (microstructures in materials or textures in images) characterizes mathematical models both in the natural sciences and in computer vision and imaging. Our interdisciplinary work capitalizes on the similarity of the mathematical tools involved: differential geometry, calculus of variations and nonlinear partial differential equations. One highlight has been the rigorous understanding of lower dimensional elasticity theories. Our research in this area emphasizes the understanding of concrete phenomena and the analysis of challenging applications over the development of abstract theory. In close interaction with the numerical analysis groups the modeling and analysis knowledge leads to fast and reliable numerical algorithms.

C Research in

Discrete Mathematics

Our research covers several aspects of Discrete Mathematics with a special focus on results that are motivated by applications in Chip Design. In a worldwide unique industrial cooperation, we develop mathematical foundations and algorithms for designing next-generation computer chips, the most complex structures that mankind has ever developed.

- **Combinatorial Optimization**
- **Chip Design**

Example: "Chip Design"

Picture: A placement of a system controller which was computed with the BonnTools.

Algorithmic challenges in numerous applications, for example chip design, are driving forces in the development of combinatorial optimization and algorithm design. In these applications, various, often very hard, optimization problems must be quickly solved. Extremely large discrete problems have to be solved for the development of computer chips. Their design is no longer possible without mathematical methods, especially those of discrete mathematics. The mathematical theory goes directly into the BonnTools, algorithms for chip design developed in this project. This has given them a competitive edge and provides the basis for their worldwide success.

D Research in

Geometry and Topology

Research on Differential Geometry and Algebraic Topology is broadly represented in Bonn.

- **Differential Geometry**
- **Topology**

Example: "Structures and invariants in algebra and topology"

*Picture: An E_8-configuration of eight tangent bundles of a 1-sphere.*

The activities of this Research Area aim at the interplay of geometry, topology, algebra and group theory. The topics range over the classification of manifolds, algebraic K- and L-theory of group rings, the geometry and homology of mapping class groups, equivariant and global homotopy theory and categorification of knot invariants and group algebras. They lead to explicit invariants in geometry and topology, are designed to answer specific questions and solve specific problems and lead to a better and deeper understanding of important general structures. These are of basic and fundamental interest and will open the door to new questions.

E Research in

Numerical Mathematics and Scientific Computing

Our research covers diverse aspects of Computational Mathematics and its applications in science and economy.

- **Numerical Simulation in Virtual Material Design**
- **Multiphase Fluid Dynamics**
- **Efficient and Reliable Numerical Solution of Problems involving Uncertainty**
- **Compressed Sensing**
- **Mathematical Methods in Imaging and Computer Vision**
- **High Performance Computing**

Example: ''High-Dimensional problems and multi-scale methods''
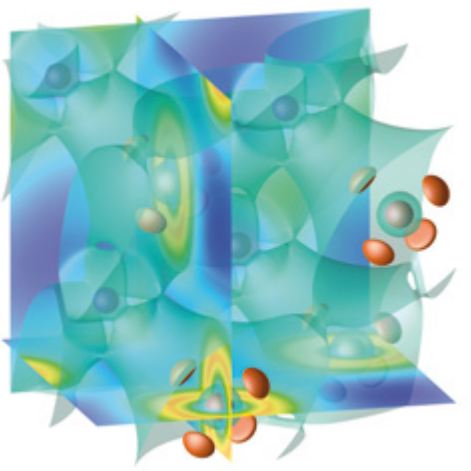
Picture: Electronic structure of crystalline gallium arsenide

Mathematical modeling of physical phenomena often leads to high-dimensional partial differential equations. Examples include the many particle Schrödinger equation in quantum physics, reaction mechanisms in molecular biology, or models for the pricing of financial derivatives. In the numerical treatment, the so-called curse of dimension is encountered. The computational cost required for an approximate solution scales exponentially with the dimension of the problem and thus renders classical numerical approaches useless in practice. Therefore, the work focuses on dimension-independent methods as well as on simplified effective models describing the macroscopic behavior of large high-dimensional systems.

F Research in

## Probability and Stochastic Analysis

Probability Theory deals with the fundamental mathematical concepts of random variables, stochastic processes and random fields. Describing random evolutions in terms of stochastic differential equations, stochastic flows, or in terms of the stochastic calculus of variations are central approaches of stochastic analysis. Active research topics in Bonn also include Optimal Transport, Markov Processes (convergence to equilibrium, functional inequalities, metastability, Markov Chain Monte Carlo), random matrices, interacting particle systems and scaling limits.

- **Probability Theory and Mathematical Statistics**
- **Stochastic Analysis**

Example: ''Stochastics in discrete, singular and infinite dimensional structures''

Picture: Random surface generated from Bernoulli last passage percolation

Stochastic models play an increasingly important role in the modeling of complex systems in almost all fields of science, economics and technology. The analysis of these models requires the development of new and sophisticated mathematical techniques. The HCM Research Area "Stochastics in discrete, singular and infinite dimensional structures" covers this entire range with special focus on issues in physics, biology and economics. Models analyzed are discrete models such as stochastic particle systems and stochastic Ising models, stochastic differential equations and stochastic partial differential equations and infinite dimensional combinatorial structures.
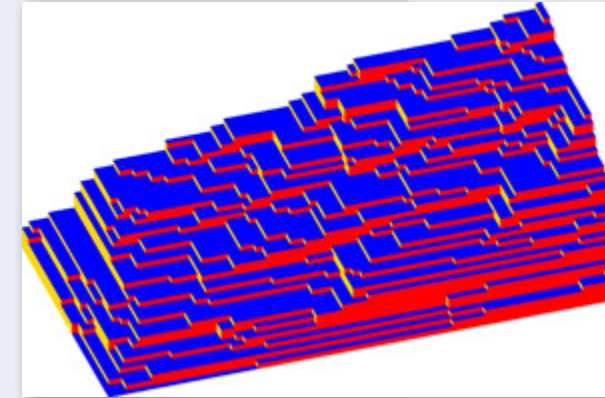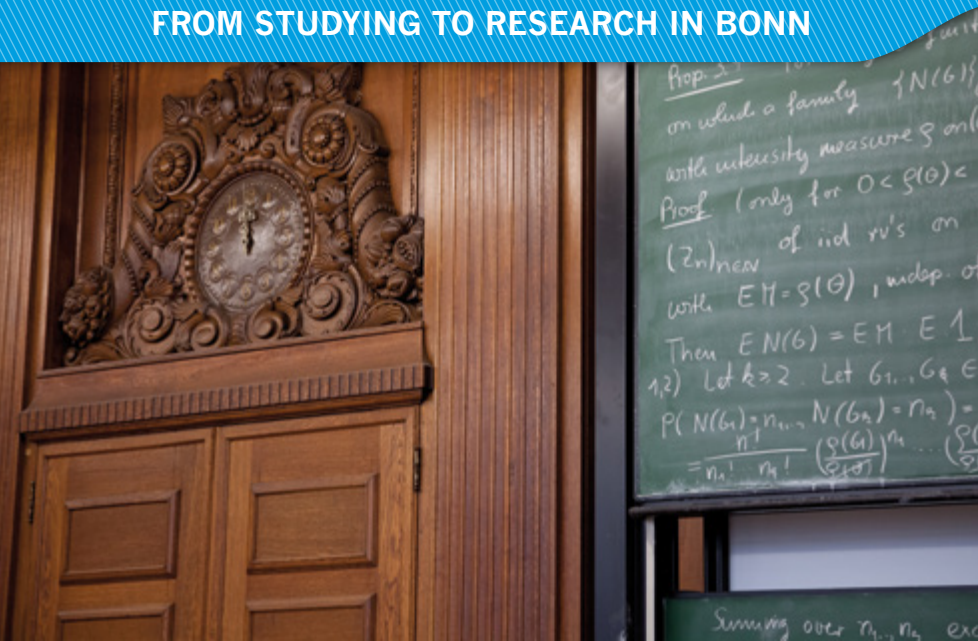
What makes our Master's program attractive?

- You will profit from the unique atmosphere created by excellent researchers and highly gifted students.
- With 45 professors, Bonn University has the largest department in mathematics within Germany.
- We offer you an extremely broad range of mathematical teaching and research opportunities.
- Our program allows a high degree of freedom in the choice of your courses. Thorough specialization is possible.
- You will work on a one year Master's thesis, your independent body of research. This means that you become an active part of a research group already during your Master's studies.
- You will learn to present mathematics in different graduate seminars.
- We offer interdisciplinary studies through an optional secondary subject.
- You can gather work experience through an optional internship or by tutoring problem sessions for younger students.
- A mentor will guide you through the course of your studies.
- There are no tuition fees.

The Master's program in Mathematics at the University of Bonn is a good entrance point for students from other universities. With the solid background of a three-year Bachelor's program, students can deepen and broaden their knowledge, particularly in a chosen field of specialization.

3. Master Studies

3.1 GENERAL INFORMATION

The Department of Mathematics at the University of Bonn offers two study programs: the Bachelor's program and the Master's program. The Bachelor's program in Mathematics is a three-year study program taught in German. The consecutive Master's program in Mathematics is a two-year study program. The language of instruction is English.

The aim of our Master's program is to direct and accompany the student to the forefront of knowledge in one of the major fields in mathematics. It is an ambitious program focused on research. The successful completion of the Master's program is excellent preparation for further graduate studies. If your ultimate goal is a doctoral thesis, you will find ideal opportunities to work here.

FROM STUDYING TO RESEARCH IN BONN

German Study System

Today's Bachelor-Master system is a result of the Bologna-Process initiated in 1999 with the aim to standardize Europe's higher education system. Thus, degrees from different European countries are comparable.

The study program is divided into a multitude of modules, including lecture courses, seminars, or practical training courses. Beside the lecture courses, seminars offer a more active way of learning: students prepare and give mathematical talks about individual topics. Each module is allotted a certain number of credit points. By means of the European Credit Transfer and Accumulation System (ECTS), your collected credits (and grades) may be transferred when changing the program or university.

Academic calendar

Winter term	October 01 – March 31
Lecture period	October – February
Summer term	April 01 – September 30
Lecture period	April – July

It is advisable to start your studies in the winter term.

Application

If you have decided to apply for the Bonn Master's program in Mathematics, your first step is to make sure that you fulfil all requirements. You must hold a Bachelor's degree (or equivalent) in Mathematics and provide proof of your English language proficiency. Further requirements are specified in the examination regulations of our Master's program.

Then you have to fill in the online application form. We kindly ask you to read carefully the information on our homepage concerning the application process:

➜ **www.mathematics.uni-bonn.de**

Only online applications will be considered. Please keep in mind that a profound mathematical knowledge comparable to a German Bachelor in Mathematics is required to succeed in our Master's program.

Please do not hesitate to contact us if you need advice.

Application deadlines
Please inform yourself about the application deadlines here:

www.mathematics.uni-bonn.de

Tuition, Fees & Cost of Living

Bonn is situated in the state of North Rhine-Westphalia (NRW), the most populous of the 16 federal states of Germany. In NRW students do not pay a tuition fee. There is an administrative fee of approximately 250 Euro per term; it includes free public transport.

The total cost of living in Bonn averages 600 – 800 Euro per month, depending on your personal standards. Health insurance is compulsory and monthly fees are about 75 Euro.

You can find further information on "Living in Germany" on the website of the German Academic Exchange Service (DAAD):

➜ **www.daad.de**

Funding Possibilities

The University of Bonn provides some scholarships for international students:

- *Scholarship plus* is a university-wide scholarship program for excellent Master students from emerging and developing countries. The aim is to attract gifted young academics to the program and to enable them to obtain a final degree through financial aid as well as an integrating program.

- *Qualifying Hausdorff* scholarships for Master students are intended to attract students with an excellent Bachelor's degree in mathematics from outside Germany who wish to enter a preparatory phase for our PhD program.

Further scholarships are available from various national organizations for exceptionally qualified candidates. Unfortunately, there are far more applicants than available scholarships. Please check the scholarship database of the DAAD for detailed information on the various programs.

Paid Student Assistantships such as teaching problem sessions or working at the library are a common source of supplementary funding. For most of these positions you need good language skills in German.

3.2 STUDY PROGRAM

The modules of the Master's program in Mathematics in Bonn are categorized into six areas:

A   **Algebra, Number Theory and Logic**

B   **Analysis and Differential Equations**

C   **Discrete Mathematics**

D   **Geometry and Topology**

E   **Numerical Mathematics and Scientific Computing**

F   **Probability and Stochastic Analysis**

and classified according to their form and level:

- *Foundations* are optional lectures courses preparing for the graduate courses.
- *Graduate Courses* are advanced lecture courses.
- In *Graduate Seminars* students present mathematics in talks.
- *Practical training courses* can be, for example, practical teaching courses (tutoring problem sessions), internships or programming projects.
- For the *Master's thesis* the typical working time is 12 months. The *Master's thesis* is accompanied by the *Master's thesis seminar*, where the students give talks about their progress.

Students interested in applications of mathematics in other sciences are encouraged to choose a secondary subject.

In this document we can only give a first impression of the offered courses. For a complete list with detailed descriptions, please visit our homepage.

→ **www.mathematics.uni-bonn.de**

Area A – Algebra, Number Theory and Logic

Algebra, Number Theory and Logic are core topics of pure mathematics. They are represented broadly in the Bonn Bachelor and Master curricula.

The label **Algebra** covers a vast range of areas such as Algebraic Number Theory, Arithmetic Algebraic Geometry, Complex Algebraic Geometry, Representation Theory and Lie Theory.

Mathematical Logic comprises Set Theory, Generalized Computability Theory, Proof Theory and Model Theory.

The modules *Advanced Algebra I*, *II*, *Algebraic Geometry I*, *II* and *Representation Theory I*, *II* are introductions and are followed by advanced and more specialized courses.

The modules *Models of Set Theory I*, *II* present an introduction into Axiomatic Set Theory, followed by advanced courses in Set Theory and other areas of logic.

Some necessary basic knowledge can be obtained in the Foundation courses *Algebra I*, *II* and *Set Theory*.

Advanced courses on Algebra treat, for example, Deligne-Lusztig varieties, loop groups, the geometric Langland's program, Kazhdan-Lusztig theory, quantum groups, triangulated categories, categorification of knot invariants, cluster algebras and their categorifications, K3 surfaces, Donaldson-Thomas invariants, moduli spaces etc.

Advanced courses on Logic treat, for example, inner models of set theory, infinite combinatorics and large cardinals, descriptive set theory, ordinal computability theory and formal mathematics.

Area B – Analysis and Differential Equations

Analysis is a central area of mathematics, which deals with the relation between the local and global behavior of functions and provides a bridge between pure and applied mathematics. Bonn offers an unusually rich spectrum of topics, ranging from pure mathematics, such as index theory and noncommutative geometry, to applications, such as materials science, classical and quantum mechanics, image processing. Three groups of core lecture courses and several advanced lecture courses are offered.

Nonlinear Partial Differential Equations (PDEs) I and II cover the main types of nonlinear PDEs and their applications. *Nonlinear PDE I* deals with nonlinear elliptic and parabolic PDEs, whereas *Nonlinear PDE II* discusses hyperbolic PDEs, including Schrödinger's equation and a selection of more advanced examples. Both courses build upon a solid knowledge of functional analysis and linear partial differential equations obtained during the Bachelor studies.

Real and Harmonic Analysis focuses on Fourier and Harmonic Analysis, including the Calderon-Zygmund theory. The key background is measure theory, functional and complex analysis.

Advanced Global Analysis I and **II** cover advanced topics as for example index theory, spectral geometry, noncommutative geometry and representation theory, building upon the basic material on global and functional analysis that is treated in the Bachelor courses.

Advanced lecture courses in Analysis and PDE build upon the core lecture courses and treat a wide selection of topics, mainly related to the research themes in Analysis in Bonn, which include mathematical modeling, mathematical physics, models from elasticity and plasticity, nonlinear waves, evolution equations, scattering theory, biological models, spectral theory of geometric differential operators on manifolds, multiscale models and the calculus of variations.

Area C – Discrete Mathematics

Algorithmic challenges in numerous applications, for example Chip Design, are driving forces in the development of Combinatorial Optimization and Algorithm Design. The core lecture courses in Area C introduce the algorithmic problems and solutions required in chip design as well as advanced knowledge in Combinatorial Optimization and Approximation Algorithms. Several advanced and selected courses and graduate seminars are offered each year and focus on recent developments in this area.

Foundations in Discrete Mathematics introduces the theory of linear and integer programming and covers basic combinatorics, graph theory and matroid theory.

Combinatorial Optimization covers topics like matchings, b-matchings and T-joins. Optimization over matroids and minimization of submodular functions are treated. Moreover polyhedral combinatorics and NP-hardness are subjects of this lecture.

Approximation Algorithms gives a thorough introduction to the theory of discrete approximation algorithms for NP-hard problems, for example set and vertex covering, MAX-Sat, TSP, knapsack, bin packing, network design and facility location. Various techniques for designing and analyzing approximation algorithms are treated. Inapproximability results are derived from the PCP-Theorem.

Chip Design is one of the most interesting application areas of mathematics and is a focus in Bonn. The course covers the algorithmic topics appearing in state-of-the-art design flows of VLSI-chips. These include, for example, logic synthesis, placement, global and local routing, timing analysis and clock tree design.

Research Institute for Discrete Mathematics / Arithmeum

Advanced courses on Discrete Mathematics focus, for example, on

- Facility Location
- Multicommodity Flows
- Steiner Trees
- Travelling Salesman Problems
- Scheduling
- Flows Over Time

Area D – Geometry and Topology

A broad range of topics from Geometry and Topology are represented in the Bachelor and Master curiccula at the University of Bonn. Furthermore, the connections to Global Analysis and Algebraic Geometry are also emphasized.

In **Topology**, the main fields are Algebraic Topology, Differential Topology and Homotopy Theory. The basic courses cover – after a general course on point set topology and elementary differential geometry – the singular homology and cohomology theory and the beginnings of homotopy theory. The more advanced courses then cover homotopy theory, bordism theory, K-theory and cohomology of groups. Finally, more specialized courses are oriented towards the reserach of the faculty members.

In **Geometry**, the basic courses comprise the theory of Riemannian manifolds, i.e., the various notions of curvature. The advanced courses deal with symplectic geometry, geometric analysis, complex algebraic geometry and geometric group theory. Specialized courses are research-oriented, dealing with topics like moduli spaces.

Advanced courses in Geometry focus, for example, on

- Riemannian Geometry
- Symplectic Geometry
- Mapping class groups
- Geometric evolution equations

Advanced courses in Topology focus, for example, on

- Topology of 4-manifolds
- Spectra and Cohomology theories
- Cohomology of groups
- Surgery theory
- Algebraic K-theory

Area **E** – Numerics and Scientific Computing

Numerical simulations are at the heart of various research efforts in science, medicine and industry. The core lecture courses in Area E offer an in-depth treatment of the theory of numerical approximation schemes and their efficient implementation. A broad selection of Advanced and Selected Topics Courses and Graduate Seminars is offered each year. They focus on applications of numerical methods in the natural sciences, engineering and economics, connections of computational mathematics to other branches of pure and applied mathematics, or recent progress in numerical analysis, efficient simulation and scientific computing.

Foundations in Scientific Computing gives a thorough introduction to theoretical and practical aspects for the efficient numerical solution of boundary and initial-boundary value problems with partial differential equations.

Numerical Algorithms introduces numerical methods for conservation laws, theoretical and practical questions of boundary element methods and integral equations, or geometric variational problems.

Numerical Simulations covers more advanced techniques for the computation of coupled field problems, optimization problems with partial differential equations, stochastic partial differential equations or fast solvers.

Advanced courses on numerical mathematics mainly focus on

- Numerical methods for nonlinear variational problems
- Convex optimization methods
- Theoretical and numerical aspects of wavelets
- Regularization of inverse problems

Advanced courses on scientific computing treat amongst others the following topics

- Numerical methods for high-dimensional problems
- Computing with high order finite elements
- Parallel algorithms in computational mathematics

Laboratories in computational mathematics aim at gaining programming experience for example in

- Numerical simulation (Topics include computational finance, computational fluid dynamics, particle and meshless methods)
- Mathematical methods in image processing

Area **F** – Probability and Stochastic Analysis

Randomness is at the heart of many current developments in mathematics and the sciences. The core lecture courses in Area F introduce the theory of stochastic processes and stochastic analysis in depth. A broad selection of Advanced and Selected Topics Courses and Graduate Seminars offered each year focuses on applications of stochastic methods in the natural sciences, economics and engineering, connections of probability theory to other branches of mathematics, or recent theoretical progress in probability, stochastic analysis and statistics.

Foundations in Probability and Stochastic Analysis introduces the theory of stochastic processes in discrete and continuous time and stochastic calculus based on Brownian motion.

Stochastic Analysis gives a thorough introduction to stochastic integrals based on semimartingales including selected more recent developments such as stochastic calculus with jumps, numerical methods for SDE, or analysis on Wiener space.

Markov Processes covers Markov processes in continuous time and related martingale problems. The connection to semigroups and generators is established and fundamental classes of models for stochastic dynamics and spatial random systems are presented.

Advanced courses on Applied Probability focus, for example, on

- Mathematical Statistical Mechanics (Phase transitions, metastability and ageing, percolation, scaling limits, SLE, random environments)
- Random Matrices and Interacting Particle Systems
- Branching Processes and Population Biology
- Stochastic Finance (Option pricing, econometrics, optimal stopping)
- Monte Carlo Methods (Numerical methods for SDE, MCMC, filtering)

Advanced courses on Probability Theory treat, for example,

- Reversible Markov Processes and Dirichlet forms (Potential theory, convergence to equilibrium, probability on graphs and networks)
- Analysis on Probability Spaces (Malliavin calculus, Stochastic partial differential equations, Analysis on metric measure spaces)
- Limit Theorems (Large deviations, extreme value statistics)
- Stochastic Differential Geometry (SDE on manifolds, heat kernels)
- Optimal Transport and Functional Inequalities

4. Going Abroad

Besides improving foreign language skills and gaining insights in a different culture, studying abroad broadens the view on mathematical topics. Gaining personal experience is another reason for exploring a foreign country. Depending on your intentions and the time you are willing to invest, you can either study one or two semesters abroad or apply for an external internship. If you are interested in spending one or two semesters abroad, you should start planning one year ahead.

Of particular interest might be the European exchange program ERASMUS that offers advice, mentoring and financial support. Please make sure that the courses you intend to take during your stay abroad can be credited to the Master's program in mathematics at the University of Bonn and that you meet the language requirements for the host university. Kindly contact the Bachelor-Master Office for more information. For detailed information about the ERASMUS Program in general, please contact the coordinator of the ERASMUS exchange program and visit the homepage:

➜ **www.math.uni-bonn.de/erasmus**

For some students the "direct exchange program" of the University of Bonn, offering exchange programs with partner universities in overseas, might be of interest as well. Please be aware that this program is highly competitive and students are expected to meet not only academic and language requirements, but are also expected to be able to act as an ambassador for the University of Bonn and Germany as a place to study. For more information:

➜ **www.direktaustausch.uni-bonn.de**

The map shows current partner universities of the mathematics department in Bonn.

5. PhD Studies

5.1 GENERAL INFORMATION

The aim of the PhD program is to educate and train the student towards independent research in a specific field of mathematics. This is achieved by research work as well as course and seminar work, all leading to a dissertation containing original research.

The PhD program in Bonn is mentor oriented. This means that a student joins the work group of a supervisor who guides the student through his or her research work. It is in cooperation with the supervisor and the working group that the student decides on the course of his or her study program. There are no specific requirements, but there is a large spectrum of lectures and seminars to choose from.

We currently have about 130 graduate students with dissertation projects in all areas of mathematics. Their supervisors are the professors of the four institutes forming the department of mathematics (Pure Mathematics, Applied Mathematics, Numerical Simulation and Discrete Mathematics) and from the affiliated Max Planck Institute for Mathematics.

5.2 BONN INTERNATIONAL GRADUATE SCHOOL IN MATHEMATICS (BIGS MATHEMATICS)

BIGS Mathematics provides a framework for the activities within the PhD program. Thus BIGS

- recruits and selects graduate students,
- screens the funding possibilities for new PhD candidates,
- helps in particular foreign students in all administrative matters inside and outside the university,
- invites guest lecturers,
- supports financially PhD students travelling to conferences,
- organizes special events like the Plücker Lectures, annual poster sessions and social activities for PhD students,
- organizes supporting exchange programs with partner universities such as Princeton, Berkeley, Kyoto, or Warwick.

In order to attract the best qualified students, BIGS Mathematics has scholarships available for top-level applicants.

- For a selected group of graduate students, there are grants of 1,468 Euro per month for a maximum of 3 years. Nomination for such a scholarship depends on an outstanding academic record.
- There are further qualifying grants of 800 Euro per month for a maximum of 1 year. These are scholarships for very promising students who need one more year to start their PhD work.
- There are further qualifying scholarships of 800 Euros per month for a period of two years. These scholarships are intended to attract students from outside Germany with an excellent Bachelor's degree who wish to enter a preparatory phase for our PhD program.

BIGS Mathematics has funding for academic travel and research stays. Graduate students are encouraged to attend conferences or visit other universities for extended stays.

Several named lecture series also take place on an annual basis. They all involve leading international experts and provide students with excellent views on cutting edge research. There are the Plücker Lectures, two lectures in the winter term, directed at graduate students in applied and pure mathematics, offering them the opportunity for interaction across research areas. The Plücker Lecture held in December 2011 was filmed and is available online – you will find the link to the podcast here:

→ **www.bigs-math.uni-bonn.de/en/events/eventpages/pluecker-lecture/ pluecker-lecture-2011**

The Felix-Klein Lectures take place once a year over a period of several weeks. They introduce graduate students to one of the hot topics in pure mathematics. The aim and format of the Lipschitz Lectures in applied mathematics are similar, but there may be several lecture series per year. Furthermore, the Hausdorff Research Institute (HIM) hosts intensive Trimester Programs, in various special areas of mathematics, which may also be of interest to doctoral students in Bonn.

5.3 GRADUATE STUDIES AND RESEARCH PROGRAMS

Within the scope of BIGS Mathematics, several independently funded long-term research programs and research training programs aim at attracting and promoting researchers at an early stage of their careers, i.e., PhD students:

- The Research Training Group (Graduiertenkolleg GRK 1150) "Homotopy and cohomology" offers PhD grants and qualifying grants.
- The International Max Planck Research School (IMPRS) offers PhD grants.
- The Collaborative Research Center (SFB) Transregio 45 "Periods, moduli spaces and arithmetic of algebraic varieties" offers positions for PhD students.
- The Collaborative Research Center (SFB) 611 "Singular Phenomena and Scaling in Mathematical Models" offers positions for PhD students.
- The Research Institute in Discrete Mathematics offers positions for PhD students within the research project "Chip Design".
- The Fraunhofer Institute for Algorithms and Scientific Computing SCAI offers positions for PhD students.

6. Career Paths

Mathematicians are in high demand in the job market as they can be employed in many different fields. A degree in mathematics qualifies for research and development, actuary work and also for management positions. In all areas, analytical thinking and the ability to understand new and highly complex processes quickly are often more important than specialized knowledge. Mathematicians are among the best paid academics.

Perspectives

Economics

You will typically find mathematicians in the insurance and credit sector, in market research bureaux and as actuaries in banks or insurance companies.
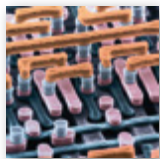
Computer Science

On many levels, software development requires mathematical thinking, whether for developing efficient algorithms or for finding creative solutions to programming problems.
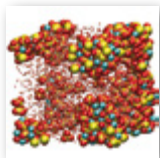
Industrial Research and Development

In the automobile and aeronautic industries, in the energy sector or in medical and biotechnology, mathematicians develop computer-based models and solve optimization problems.

Academic Career

About 4,000 mathematicians are employed at German universities, most of them as scientific assistants. Jobs as scientific assistants are usually limited in time and should be used for further scientific qualification (e.g. a PhD).

Many of the German mathematics professors have passed through the University of Bonn at some stage in their careers.

7. Contact & Counselling

ACADEMIC COUNSELLING

For all questions concerning your studies, you are welcome to contact us:

Bachelor-Master Office
Endenicher Allee 60, 53115 Bonn

phone: +49 (0) 2 28 73-31 80

bama@math.uni-bonn.de

➔ **www.mathematics.uni-bonn.de**

STUDENT COUNCIL

At the University of Bonn, students' interests are represented by various councils. In particular the "Fachschaft Mathematik" promotes the rights and interests of maths students, representing students' positions in discussions concerning university politics. Furthermore, the "Fachschaft" organizes welcome events for new students and many other get-togethers, like parties, wine & cheese evenings and a ball. Above all, the "Fachschaft" gives advice to enrolled and prospective students and tries to help them with their study related issues.

If you have any questions or concerns, do not hesitate to contact

➔ **master@fsmath.uni-bonn.de**

➔ **www.fsmath.uni-bonn.de**

IMPORTANT LINKS

The Department of Mathematics, including all information on our study programs
➜ **www.mathematics.uni-bonn.de**

Course overview of the University of Bonn
➜ **www.basis.uni-bonn.de**

Hausdorff Center for Mathematics (HCM)
➜ **www.hcm.uni-bonn.de**

Hausdorff Research Institute for Mathematics (HIM)
➜ **www.him.uni-bonn.de**

Bonn International Graduate School in Mathematics (BIGS Mathematics)
➜ **www.bigs-math.uni-bonn.de**

Max Planck Institute for Mathematics in Bonn (MPI)
➜ **www.mpim-bonn.mpg.de**

FURTHER INFORMATION

International Office

The International Office is the hub for all international activities. It coordinates international relations and develops projects and programs with partners abroad. The International Office advises and mentors international students, doctoral candidates, fellows and visiting researchers.

> **International Office**
> Poppelsdorfer Allee 53, 53115 Bonn

➜ **www.international.uni-bonn.de**

Central Student Counselling and Advisory Service

The Central Student Counselling and Advisory Service (Zentrale Studienberatung) provides information, advice and counselling to high school students, students and anyone who is interested in studying at the University of Bonn. It is a place where you can find out, among many other things, whom to contact with your specific question.

> **Zentrale Studienberatung (ZSB)**
> Poppelsdorfer Allee 49, 53115 Bonn
> phone: +49 (0) 2 28 73-70 80
>
> zsb@uni-bonn.de

➜ **www.zsb.uni-bonn.de**

Accommodation

All students registered at the University of Bonn are eligible to apply for a room at one of the 35 residence halls run by the Bonn Student Service (Studentenwerk).

Information on residence halls and how to apply can be obtained from:

> **Studentenwerk Bonn**
> Abteilung Studentisches Wohnen
> Nassestraße 11, 53113 Bonn
> phone: +49 (0) 228 73-71 63
>
> wohnen@stw-bonn.de

➜ **www.studentenwerk-bonn.de**

Studying and Parenting

Students with children are supported by the AStA Advisory Office (Beratungsstelle "Studieren mit Kind") or by the University Family Office (Familienbüro).

AStA (Allgemeiner Studierendenausschuss)
Nassestraße 11, 53113 Bonn

phone: +49 (0) 228 73-5874

smk@asta.uni-bonn.de

Familienbüro der Universität Bonn
Franziskanerstraße 4, 53113 Bonn

phone: +49 (0) 228 73-6565

familienbuero@uni-bonn.de

➜ **www.asta-bonn.de/Studieren_mit_Kind**

➜ **www.familienbuero.uni-bonn.de**

Career Center

The Career Center of the University of Bonn, a service for students and graduates, provides support for the transition from study to employment. In addition to running a job portal, the Career Center also offers job application training and workshops and career planning or networking.

Career Center
Poppelsdorfer Allee 49, 53115 Bonn

phone: +49 (0) 228 73-4689

careercenter@uni-bonn.de

➜ **www.careercenter.uni-bonn.de**

Bundesagentur für Arbeit Bonn

The team "Akademische Berufe" (academic careers) of the Bundesagentur für Arbeit also provides advice and information for students and graduates and helps them to find employment. On offer: Informational events, workshops and seminars on e.g. career starting, professional fields, applying for jobs, continuing education and entrepreneurship.

Bundesagentur für Arbeit Bonn
Villemombler Straße 101, 53103 Bonn

8. Additional Activities

Key Qualifications

Those who would like to acquire additional qualifications outside their course of study can make their choice from the classes offered by the "Zentralstelle für Schlüsselkompetenzen". Classes range from "Journalistisches Schreiben" (Journalism) to "Teamarbeit und Projektleitung" (Teamwork and Project Management), "Strukturierte und zielorientierte Gesprächsführung" (Structured and Goal-oriented Meeting Management) to "Global Working: Berufliche Entsendung ins Ausland" (Global Working: Job Postings Abroad).

Zentralstelle für Schlüsselkompetenzen
Am Hof 3–5, 53113 Bonn

phone: +49 (0) 2 28 73-18 21

zsk@uni-bonn.de

➜ **www.zsk.uni-bonn.de**

If you are interested in acquiring or improving foreign language skills, please visit the online "Sprachenportal" (language portal).

➜ **www.sprachen.uni-bonn.de**

Of course, German language courses are also among the large variety of courses.

University Sports

University sports make sure that the students and staff at the university really keep moving. Both beginners and experienced athletes may choose from among 100 different types of sports. Archery, canoeing, fencing, jazz dance, soccer, Thai Chi, Yoga are just a few examples. Most of the courses are open to students free of charge.

Cultural Activities

The Collegium musicum at the University of Bonn offers students the opportunity to complement their studies by participating actively in or just listening to musical activities. There are several orchestras, choirs and ensembles that not only perform major symphonic works, famous oratorios and chamber music but also film music, jazz and experimental compositions.

Several drama groups and a ballet studio provide opportunities for practicing and joining. If you like, you can become active within the Ausstellungsgruppe (exhibition group) of the Kunsthistorisches Institut, which organizes a contemporary art exhibition every semester. Creative/artistic classes in painting, drawing, photography, etc. are offered by the "Atelier für Bildende Kunst".

Notes

Imprint

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Endenicher Allee 60, 53115 Bonn

➜ **www.mathematics.uni-bonn.de**

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Contact

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Endenicher Allee 60, 53115 Bonn

bama@math.uni-bonn.de

→ **www.mathematics.uni-bonn.de**