Department of
MATHEMATICS


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EWHA W.U.

Overview of Majors

Algebra

Prof. Yoonjin Lee,
Prof. Joonyeong Won

- Selected Topics in Algebra
- Selected Topics in Number Theory
- Algebraic Number Theory
- Applied Algebra
- Lie Group

Numerical Analysis

Prof. June-Yub Lee,
Prof. Chohong Min

Numerical Differential Equations
- Numerical Linear Algebra
- Selected Topics in Numerical Analysis
- Applied Differential Equations
- Numerical Method and
Scientific Computation
- Advanced Numerical Analysis
- Optimization

Faculty

Professors

Analysis

Prof. Chulkwang Kwak

Prof. Jaehyeon Ryu

- Real Analysis
- Complex Analysis
- Harmonic Analysis
- Introduction to Functional Analysis
- Partial Differential Equations

Applied Mathematics

Prof. Hyang-Sook Lee, Prof. Jungho Yoon

- Topics in Modern Cryptography
- Modern Cryptography
- Public Cryptography
- Number theory and Cryptography
- Mathematical Modeling
- Approximation Theory
- Image Processing

Topology & Geometry

Prof Jae-Hyouk Lee, Prof. Min Hoon Kim

- Differential Topology
- Algebraic Topology
- Selected Topics in Topology
- Differential Geometry
- Gauge Theory
- Global Analysis

About Us

Mathematics is the language of natural science, which is essential for human's understanding of natural phenomena.
Mathematics is clear, rigorous, and beautiful. Pure mathematics comprises algebra which studies rigid structures such as number systems, analysis which studies quantitative investigations, and geometry which studies the structure of spaces. Applied mathematics includes cryptography, image processing, n umerical analysis, optimization, as well as artificial intelligence, and addresses the real world problems that connect mathematics to natural science, engi neering, economics and sociology.

Department of Mathematics at Ewha Womans University is one of the few mathematics departments in Korea in which both pure mathematics and app lied mathematics are well balanced. Our department possesses outstanding capability and performance in both research and education.

University Disciplinary Motto

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One Who Leads

Ewha aims to cultivate in students the capacity for intellectual exploration an d creative convergence, thereby fostering them into world leaders.

H

One Who is Wise

Ewha aims to cultivate in students the capacity for art and culture and social empathy, thereby fostering them to relate to and be involved in addressing problems within their communities

E

One Who Acts

Ewha aims to cultivate in students competence as global citizens who are equi pped with social awareness and empathy and therefore able to communicate on an international level.

Course Overview

Major foundation	Calculus I Calculus II
Algebra & Cryptography	Linear Algebra I Linear Algebra II Number Theory Abstract Algebra I Abstract Algebra II Cryptography
Analysis & Applied anlaysis	Advanced Calculus I Advanced Calculus II Complex Analysis I Complex Analysis II Real Analysis Partial Differential Equation Digital Image Processing
Topology & Geometry	Introduction of Modern Mathematics Multivariable Calculus Topology I Topology II Differential Geometry I
Numerical Analysis	Mathematical Sciences and Information Discrete Mathematics and Programming Differential Equations Numerical Analysis Numerical Differential Equations

Interdisciplinary Majors

Computational Science

Educational objectives

We provide an opportunity to understand natural and social phenomena through computational science, based on the student's own major. Through the "computation al science" interdisciplinary major, we aim to let students learn basic knowledge in ma thematics, natural science and computer science, as well as to raise students capable of applying the methods of computational science to problems in science and engineering .

We aim to foster students who have the knowledge in various areas and the computer skills to apply such knowledge, and are capable of solving crucial problems in science and technology of the future.

Application and Requirements

Time to Apply | 1st semester: April, 2nd semester: October

Requirements | Double major – minimum of 30 credits*, Minor – minimum of 21 credits**

*Including 6 credits of interdisciplinary major necessary courses
**Including 3 credits of interdisciplinary major necessary courses

Thesis Submission | end of May, end of November

Information Security

Educational objectives

In the information society, as the usage of internet spreads throughout the world and becomes part of daily life, and as information security forms one of the fundamentals of information technology, professionals in information security are needed. Through the "information security" interdisciplinary major, we aim to let students to learn infor mation technology (IT) and the knowledge in information security, as well as to raise students with professional knowledge and skills in this area.

We aim to foster students who are proficient at advanced computer technology and v arious newest security technologies required in the 21st century information society, a nd who can solve problems in information security.

Our Faculty

Number Theory and Coding Theory Lab

Prof. Yoonjin Lee

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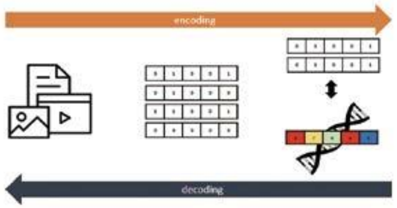
Research Area

Number Theory and Algebra belong to the major areas of mathematics, and they can be applied to Coding Theory, a part of Information Theory. We broadly study the arithmetic of function fields and number fields: structure of class groups, nonvanishing of the L-functions over function fields, surjectivity of Galois representations associated with Drinfeld modules, torsion groups of elliptic curves, and so on. Furthermore, we focus on construction of "good" error-correcting codes, which is one of two major themes of Coding Theory for minimizing the loss of information transmitted through noisy channels. We study a variety of interesting code classes such as self-dual codes, cyclic codes, LCD codes, DNA codes, quantum codes, convolutional codes (turbo codes) and so forth. Graduate students in this lab currently study the arithmetic of function fields and number fields, a variety of algebraic codes (self-dual codes, cyclic codes, LCD codes, convolutional codes, and etc.) and cryptographic functions (bent functions, plateaued functions).

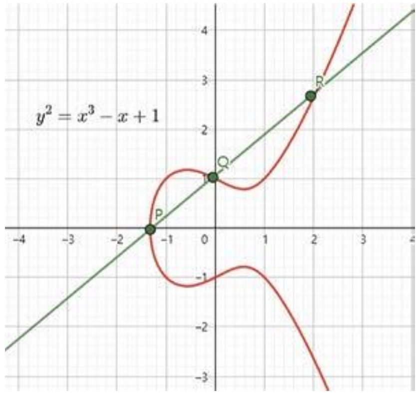
Algebraic Coding Theory

- Arithmetic of number fields and function fields
- Arithmetic of Drinfeld modules
- Structure of ideal (or divisor) class groups of global function fields and number fields
- Non-vanishing of L-functions for various characters in function fields
- Modularity of various types of continued fractions
- Torsion group structure of elliptic curves and hyperelliptic curves



Algebraic Coding Theory and Discrete Mathematics

- Self-dual codes, Formally self-dual codes
- Cyclic codes, Quasi-cyclic codes
- Algebraic geometry codes, Reed Solomon codes
- Convolutional codes, LCD codes, DNA codes
- Cryptographic functions: Bent functions and Plateaued functions
- Strongly regular graphs, Few-weight codes



Algebraic Geometry Lab

Prof. Joonyeong Won

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Research Area

Algebra is a field of study that primarily focuses on polynomial equations. When a geometric object, a variety or manifold, is given as the set of roots of a polynomial equation, it is called an algebraic variety. Using algebraic methods, researchers study and classify the characteristics of geometric obje cts, based on birational morphisms. Kähler complex manifolds are classified into three types: general type, Calabi-Yau, and Fano.
This study focuses mainly on Fano varieties, which are rational varieties that are close to or can be birationally transformed into projective spaces. In addition, research is underway to derive algebraic propositions using geometric properties.

Research on Complex and Algebraic Geometry

One of the most essential problems in complex or algebraic geometry is whether a Fano manifold possesses a Kähler-Einstein metric. This problem or iginated from the existence problem of solutions to the Monge-Ampère equation in complex or differential geometry. However, it has been revealed t hat this existence is equivalent to a complete algebraic stability problem called K-stability. Therefore, researchers are studying this K-stability by meas uring algebraic invariants such as alpha or delta invariants, which are tools for determining K-stability. The ultimate goal is to classify the existence o f Kähler-Einstein metrics on all Fano manifolds.

Research on Complex and Algebraic Geometry

One of the famous conjectures is that the rational points on Fano manifolds are potentially dense. The term "potentially dense" means that rational poi nts on an algebraic variety defined over a given field (K) become dense when extended to a finite extension of K, which is essentially a problem in nu mber theory. This problem is studied based on geometric properties.

Analysis & PDE Lab

Prof. Chulkwang Kwak

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Research Area

Analysis helps us to understand in mathematical languages various phenomena arising from the fields of not only mathematical sciences, but also reality. Particularly, nonlinear Partial Differential Equations(PDEs) describe such phenomena, and enable to predict future phenomena based on the study of existence and global dynamics of solutions. In Analysis and PDE Lab, we particularly study theories of well-posedness and long time dynamics of solutions to nonlinear dispersive equations involving asymptotic models for water waves.

Well-posedness theory

This field aims to develop properties of nonlinear solutions from ones of linear solutions investigated by Harmonic analysis technique.

Asymptotic dynamics

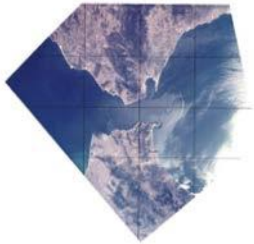
This field aims to describe global-in-time dynamics of nonlinear solutions based on dispersive properties of solutions and specific structures of equations.

Nonlinear dispersive equations

- Local and global well-posedness
- Continuum limit problems
- Decay property

Water wave models

- Asymptotic models
- Small amplitude limit
- Long time dynamics



$$
\begin{aligned}
\partial_t u - \partial_x u = 0 &\quad \int \frac{1}{2}u^2, \\
\partial_t u - \partial_x^3 u + 6u^2\partial_x u = 0 &\quad \int \frac{1}{2}u_x^2 + \frac{1}{2}u^4, \\
\partial_t u - \partial_x^5 u + 10u\partial_x u\partial_x^2 u + 10u^2\partial_x^3 u & \\
+ 10(\partial_x u)^3 - 30u^4\partial_x u = 0 &\quad \int \frac{1}{2}u_{xx}^2 + u^6 + 5u^2u_x^2. \\
\vdots \quad & \quad \vdots
\end{aligned}
$$

Harmonic Analysis Lab

Prof. Jaehyeon Ryu

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Lab Introduction

Harmonic Analysis is a branch of mathematics that studies the behavior of functions through oscillation and their representation in frequency. Fourier series expansion and Fourier transform are standard methods to conduct this study. Harmonic Analysis has become a subject of intense study in connection with diverse fields including number theory, partial differential equations, representation theory, signal processing, quantum mechanics, probability theory, and neurosciences.

Summability of eigenfunction expansions and bounds of eigenfunctions

Fourier series offers an elegant way to represent functions as sums of trigonometric functions, which are eigenfunctions of the Laplacian. A fundamental question in Harmonic Analysis is determining under what conditions the Fourier series of a given function converges to the original function. This lab focuses on studying the convergence properties of eigenfunction expansions for various types of eigenfunctions, as well as investigating the bounds of eigenfunctions in Lebesgue spaces.

Boundedness of Maximal operators

The boundedness of the Maximal operator is a subject studied intensively in Harmonic Analysis. The Hardy-Littlewood maximal operator is one of the most fundamental examples, and besides, the Kakeya maximal operator is another interesting object. This lab aims to study the boundedness of maximal operators in Euclidean spaces and the Heisenberg group.

Geometry Lab

Prof. Jae-Hyouk Lee

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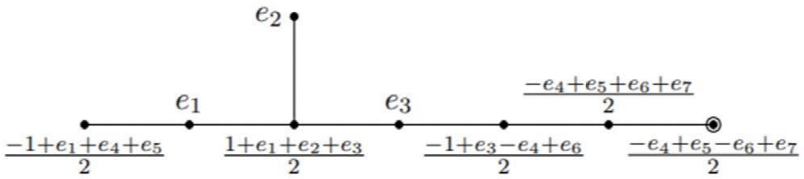
Research Area

We study differential geometry, symplectic geometry, and algebraic geometry. Distinctive characters and uniform aspects of these geometries, especially octonions, are main motives for our researches. The researches have been successfully performed in the geometry of manifolds with special holonomies, comparative study of polytopes and complex surfaces along the representations of exceptional Lie groups. Therefrom, we contribute to construct new geometric spaces and to produce creative comparative studies among them.



Coxeter-Dynkin diagram of 4_{21}.

- Geometry of polygon spaces via spin representation
- Isoparametric geometry of spheres and complex geometry of spherical varieties
- Geometry along the magic square and its complexification
- Comparative study of moment polytopes in symplectic geometry and algebraic geometry

Geometric Topology Lab

Prof. Min Hoon Kim

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Research Area

In geometric topology, we study topological spaces which locally resemble Euclidean space, called manifolds. The fundamental problem is to classify manifolds. The classification results depend on the dimension. Classifying 0 and 1-dimensional manifolds is rather trivial because there are few exam ples. It turns out that 2- and 3-dimensional manifolds admit geometric structures after cutting them into canonical pieces and we can classify them by studying their geometry. High-dimensional manifolds whose dimensions are greater than or equal to 5 are classified by (after fixing their homoto py type) some algebraic topological data via surgery theory and the s-cobordism theorem. In the intermediate dimension, namely 4, there is a striking difference between topological and smooth 4-manifolds and techniques from low-dimensional topology and highdimensional topology only partly work and classifying 4-manifolds is one of the remaining fundamental problems.

Research topic 1: Topology 4-manifolds

Classifying 4-manifolds is a fundamental problem. In this project, we investigate various research problems on 4-manifolds. Specific topics include the following: (a) To find explicit diffeomorphisms between 4-manifolds. (b) To develop techniques to compute Floer homology theoretic invariants. (c) Construct homemomorphic, but not diffeomorphic 4-manifolds. (d) Understand homology cobordisms and rational homology cob ordisms between 3-manifolds.

Research topic 2: Topology of knots and links

Knots and links are embedded circles in the 3-dimensional Euclidean space. They play a central role in lowdimensional topology. 3- and 4-dimensional manifolds can be explicitly described by knots and links. Moreover, some important classification problems of 4-manifolds can be ref ormulated as concordance problems of knots and links. We investigate various research problems on concordances of knots and links partly inspir ed by the classification problems of 4-manifolds.

Cryptography Lab

Prof. Hyang-Sook Lee

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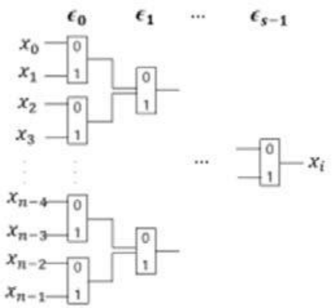
Research Area

As quantum computers are being developed in earnest, research on Post Quantum Cryptography which is a next-generation public-key cryptosystem, is being actively carried out in an environment where existing mathematical-based public-key cryptosystem is threatened by the quantum algorithm proposed by Peter Shor. Lattice-based cryptography, Isogeny-based cryptography, Code-based cryptography, and Multivariate- based cryptography without efficient attacks based on quantum algorithms are candidates for Post-Quantum Cryptography. In particular, Lattice-based cryptography has the advantages in the sense that it is efficient to calculate and provides a variety of applications. This lab focuses on the study of Post-Quantum public-key cryptography for quantum computing environments. Especially, we conduct studies on Homomorphic Encryption, Secret Sharing, Security Analysis, etc., along with studies on Lattice-based public-key cryptography which is secure and efficiently applicable in multi-party environments.

- The Multi-Party Cryptographic Application of Lattice- Based Fully Homomorphic Encryption Scheme
- Computational Mathematics for Integrated Science-Based Technology
- Lattice-based Public-Key Cryptography for IoT
- The Application of Computational-Based Mathematical Sciences
- One-Way Function for Multi-functional Cryptographic System with High-Efficiency



ϵ_{s-1}	$\dots$	ϵ_0	Data
0	$\dots$	0	x_0
0	$\dots$	1	x_1
$\vdots$	$\vdots$	$\vdots$	$\vdots$
1	$\dots$	1	x_{n-1}

Applied Analysis & Data Approximation Lab

Prof. Jungho Yoon

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Research Area

We conduct research on data approximation theories and algorithms which are fundamental components in the area of data science. We develop linear or non-linear approximation schemes for various types of data that are generated in various fields of scientific computation. Specifically, our research interests include the following topics:

Nonlinear data approximation

We develop non-linear theories and algorithm for multi-dimension (scattered) data containing various types of singular points that are arising in the areas such as image processing, fluid PDEs and computer visualizations.

Multi-dimensional large-scale data approximation

In order to handle large-scale data efficiently, we study sparse-grid approximation and multi-resolution analysis by using radial basis functions and subdivision methods.

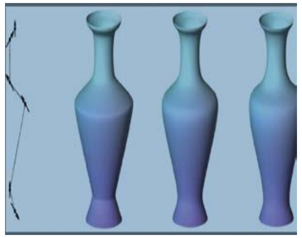
CAGD (computer aided geometric design)

We study subdivision and spline theories and algorithms for geometric modeling for computer graphics, animation, and multi-resolution analysis.

Mathematical Image processing

Based on non-linear data approximation theories, we develop algorithms of image super-resolution, image denoising, and deblurring. In addition, we solve image processing problems that occur in industries such as 3D semi-conductors and medical imaging, This research topic is being studied in connection with data science, especially deep learning algorithms of artificial intelligence.

- Scattered data approximation by radial basis function and nonlinear moving least squares method
- Approximation of multivariate functions on Sparse grid
- Subdivision for Computer Aided Geometric Design
- Mathematical Image Processing: image interpolation, super-resolution, denoising, deblurring
- Construction of nonlinear scheme for hyperbolic conservation laws



Scientific Computing Lab

Research Area

The research topics include numerical analysis, more specifically high-speed numerical methods based on the integral equations, and mathematical analysis of inverse problems using the high-speed methods. Among many research results, accelerating the non-uniform Fast Fourier Transform is a major research achievement that extends the FFT developed in 1965 and is one of the representative research achievements in the field of applied mathematics. The type3 NUFFT which extends the non-uniform Fourier transform technique, and MRI reconstruction technique using the NUFFT were studied. In addition, various studies on the inverse problem were conducted to develop the reconstruction formula, MREIT-related numerical technique, and the Equipotential method. And the polarization tensor and moment tensor methods that analyze the mathematical characteristics of the inverse problem were studied. Since 2014, research on the phase field equation such as the spectral method of the Allen-Cahn equation, the phase field crystal equation, the convex splitting RK method, and the 2nd order operator separation method are in progress. Recently, researches on scientific computation using artificial neural networks have been conducted.

Prof. June-Yub Lee

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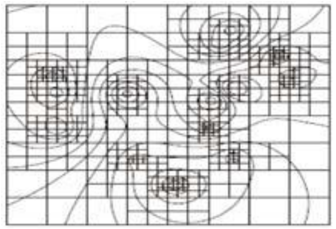
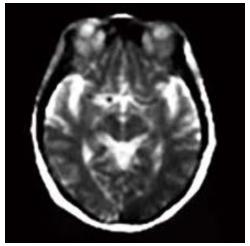
Numerical Computation Tools including Elliptic PDE solver

- Triple junction problem, Quasi-periodic direct, Parareal DC, Flux conservative
- Prolate function, Non-Uniform FFT, Fast Sinc Trans.
- Parallel Poisson solver, Poisson solver, Nonseparable elliptic PDE
- Two-point BVP, Singularly Perturbed BVP, Rosenau-Burgers Eq.



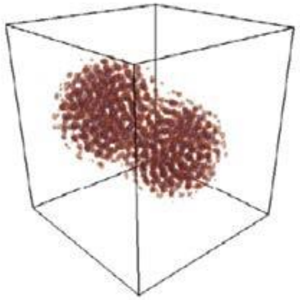


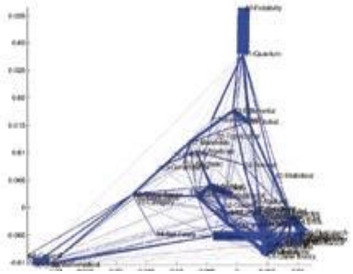
Inverse Problems and Electrical Impedance Tomography

- Thin elastic inclusion, Polarization tensors, Electrical anomalies
- Curl-J method, Equipotential line method, Forward Solver
- High Contrast Composites, Cauchy problem, Elasticity
- P-Laplacian, Free-boundary, Bernoulli type Eq.

Vortex Calculation, CFD, and Phase Field computation

- Operator Splitting : Image-segment, Semi-Analytic, PF-Crystal, Epitaxial Thin Film
- Energy-Stable Methods : CSRK, CSRK-R, cCS-vCH, CSRK-x-CH, ConvexGrad-RK
- Phase-Field Models : PFC-CS_BF, Modified PFC, PFC-CSRK-LongTime
- Long time Vortex sheet, Recirculating flow





Mathematical Education, Neural Networks (AI), and Miscellaneous

- Internet usage, Two-way communication, Graph Clustering

Numerical Analysis Lab

Prof. Chohong Min

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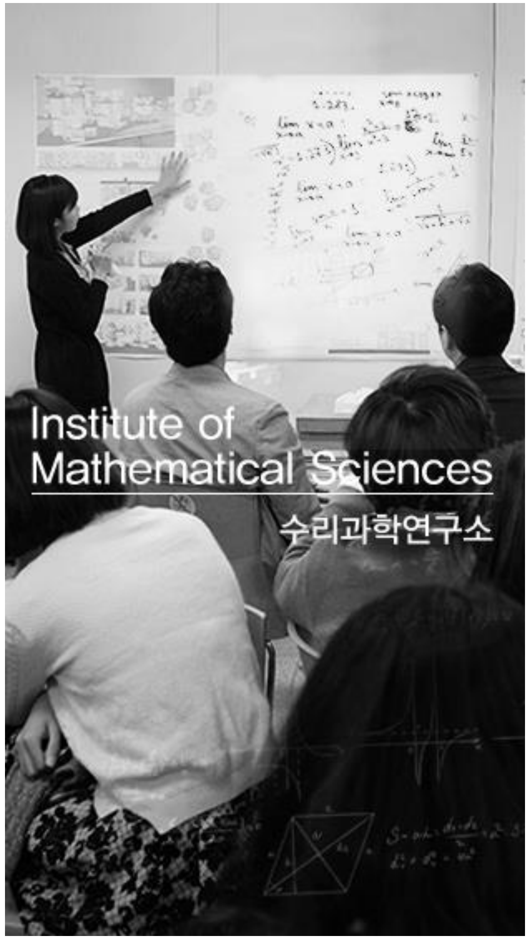
Research Area

Based on numerical analysis and optimization theories, we study the mathematical characteristics and the convergences of approximations in the area s of deep learning, homomorphic encryption and computational fluid dynamics.

Specifically, our research interests include the following topics:

- Deep learning theory
- Homomorphic encryption
- Numerical Analysis

Ewha Institute of Mathematical Sciences (EIMS)



EIMS has been contributing to the development of national industry and advance d science and technology, as well as playing a central role in creating future values , through connecting crucial technologies of the 4th industrial revolution, focusing on the Computational Mathematics based on numerical analysis, image processing, cryptography, coding, biology, and medical statistics. Through the 'Key Research Institutes in Universities of National Sciences and Engineering' program (2009–2017, 2019–2025), the institute has been fostering full-time research professionals and graduate students in the specialized areas by strengthening their research competence.

Web : http://ims.ewha.ac.kr

Undergraduate Program

Mathematics Research Program

To provide undergraduate students with opportunity to study deeper level of mathematics
,
have a research experience, and develop problem solving ability and integrative thinking.

UREP
(Undergraduate Research Experience Program)

Time to Apply	End of each semester
Eligibility	Junior, senior students
Duration of the program	Six months
Benefits	• Scholarship • Visiting overseas university

Summer/Winter Research Internship

Time to Apply	End of each semester
Eligibility	Junior, senior students
Duration of the program	Six months
Benefits	• Scholarship • Visiting overseas university

Exchange Program

Exchange students are selected each semester based on set procedures and the languages of instruction.

Duration | one semester ~ one year

*Web | http://ewha.ac.kr/ewhaen/bachelor/exchange01.do

Scholarship

T

One Who Leads

Ewha provides enough scholarships to lighten the financial burden of students, allowing them focus wholly on studying and growing into progressive professionals.

- State Scholarship (Type 1,2)
- Welfare Scholarship
- Ombudsman Scholarship
- Loan Interest Covering Scholarship
- Ewha Plus Scholarship
- Academic Scholarship

H

One Who is Wise

Ewha provides scholarships that enable students to participate in various practical, individual, social and global experiences to help them grow into mature, refined individuals.

- Future Planning Scholarship
- Self-Designed Semester Scholarship
- Student Scholar support scholarship
- Individual College Scholarship
- Major Leadership Scholarship
- Overseas Training, Exploration, Global Base Scholarship

E

One Who Acts

Ewha provides scholarships for those who want to contribute to the development of our nation and society through acts of service the spirit of love and compassion.

- Mentoring Scholarship (Dawoori, Ewha Mate, etc.)
- Tutoring Scholaship
- Volunteer Work Scholarship
- Missionary Scholarship
- Ewha Volunteer Truth, Good, beauty Scholarship
- Club Activity Scholarship

Brain Korea 21 Four

BK21 Four is a program for high level education of human resources, aiming at fostering the establishment of graduate schools at the international level and the training of outsta nding researchers. It focuses mainly on supporting graduate students and young researche rs. Our department was selected for the 2nd and the 3rd phase BK programs (2006-2020) and received good evaluations and in particular was assessed as outstanding in the over all assessment of BK21 plus program (3rd phase) in 2019. Recently, we are selected for th e 4th phase BK21 program (2020-2027), with which we have been supporting the resear ch of graduate students to a great extent.

Ewha Institute of Mathematical Sciences (EIMS)

EIMS has been contributing to the development of national industry and advanced science and technology, as well as playing a central role in creating future values, through connecting crucial technologies of the 4th industrial revolution, focusing on the Computational Mathematics based on numerical analysis, image processing, cryptography, coding, biology, and medical statistics. Through the 'Key Research Institutes in Universities of National Sciences and Engineering' program (2009-2017, 2019-2025), the institute has been fostering full-time research professionals and graduate students in the specialized areas by strengthening their research competence.

Career Path

As the era of intelligence and information began by the 4th industrial revolution of the 21st century, the importance of mathematics has been rising. In several industry areas, especially those related to Big Data and Artificial Intelligence, the demand for mathematicians has been steeply increasing. After graduation, the students proceed to graduate schools for research, development teams of leading firms, government institutes in the areas of IT, finance, security and semi-conductors, and also to other various professions such as actuaries and patent attorneys.

Research

- Graduate School (Master / Ph. D)
- The Institute for Basic Science (IBS)
- National Institutute for Mathematical Sciences (NIMS)
- Korea Institute for Advanced Study (KIAS)

Security & Communication Technology

- National Security Research Institute
- Electronics and Telecommunications Research Institute (ETRI)
- Korea Internet & Security Agency (KISA)
- Samsung SDS
- Samsung Advanced Institute of Technology (SAIT)

Education

- Korean Educational Development Institute (KEDI)
- Korea Institute for Curriculum and Evaluation (KICE)

Financial Company

- PB
- Certified Investment Analyst
- Actuary
- Damage adjuster
- Analyst
- Fund Manager
- Foreign-exchange Dealer
- Account Executive

Patent attorney / Accountant

- Patent & Law Firm
- Accounting firm

AI / Big Data

- Big Data Professionalist
- Dataminer
- Database Administrator
- Data Engineer
- Data Scientist

Requirements for Graduation

BK21 Four is a program for high level education of human resources, aiming at fostering the establishment of graduate schools at the international level and the training of outstanding researchers. It focuses mainly on supporting graduate students and young researchers. Our department was selected for the 2nd and the 3rd phase BK programs (2006-2020) and received good evaluations and in particular was assessed as outstanding in the overall assessment of BK21 plus program (3rd phase) in 2019. Recently, we are selected for the 4th phase BK21 program (2020-2027), with which we have been supporting the research of graduate students to a great extent.

Requirements for Graduation

1. Special lecture: Attendance 4 times or more
2. Graduation exam (2 subjects in total - Introduction to Analysis, Linear Algebra)
3. Application period : The semester immediately before graduation and the beginning of the semester of graduation(Example: If it is based on an 8th semester graduate, the beginning of the 7th semester and the beginning of the 8th semester)
4. Re-examination period and target : It is conducted during the semester only for those who failed the main exam at the beginning of the semester and are expected to graduate

Graduate School Application

Purpose

Through the education of fundamental concepts and the systems of modern mathematics, we raise creative female professionals required by the society, who think logically, develop relations among the adjacent areas of study, and apply these and contribute to the development of science and technology.

Program - Linked Bachelor's - Master's Degree* / Master / Ph. D / Integrated Ph. D Program

Evaluation | Document 40%, Interview 60%

Time to Apply | April and October

Scholarship | BK21, Research Assistant, Teaching Assistant, etc.

* Linked Bachelor's - Master's Degree

This program allows undergraduate students to obtain both Bachelor's degree and Master's degree in 5 years or 5 and a half years by shortening one or two semesters.

Ewha Womans University Department of Mathematics

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