Doctor of Philosophy Program in Mathematics
(International Program/ Revised Program 2020)
Department of Mathematics

Program Title

Thai	หลักสูตรปรัชญาดุษฎีบัณฑิต สาขาวิชาคณิตศาสตร์ (หลักสูตรนานาชาติ)
English	Doctor of Philosophy Program in Mathematics (International Program)

Degree Title and Academic Discipline

Thai	ปรัชญาดุษฎีบัณฑิต (คณิตศาสตร์) ปร.ด. (คณิตศาสตร์)
English	Doctor of Philosophy (Mathematics) Ph.D. (Mathematics)

Place of Instruction

Faculty of Science, Silpakorn University, Sanamchandra Palace, Nakhon Pathom

Program objectives

1. To produce mathematicians who have good qualities, knowledge and understanding, and are able to effectively transfer mathematical knowledge to others.
2. To produce researchers in pure mathematics or applied mathematics who are capable of conducting research at an international standard.
3. To produce mathematicians who have morality and ethics in research and publication.
4. To produce graduates who have responsibilities, honesty and discipline, and are able to work effectively with others.

Student qualifications

1. Student qualifications for each type of study plan

1.1 Type 1.1 Thesis equivalent to 48 credits

Graduates with a master's degree or equivalent in mathematics or related fields, with a GPA of 3.25 or higher, or by department's approval

1.2 Type 1.2 Thesis equivalent to 72 credits

Graduates with a bachelor's degree with honors in science or equivalent in mathematics or related fields

1.3 Type 2.1 Thesis equivalent to 36 credits and additional courses not less than 15 credits.

Graduates with a master's degree or equivalent in mathematics or related fields

1.4 Type 2.2 Thesis equivalent to 48 credits and additional courses no less than 27 credits.

Graduates with a bachelor's degree with first-class honors or equivalent in mathematics or related fields

2. Candidates must provide proof of English proficiency from a language institute at CEFR standard at a minimum of A2 level as specified by the university.

3. Candidates who do not have all the qualifications in 2.2.1 must have their cases considered by the program committee and the dean of the graduate school.

Program structure

1. Type 1 (Thesis)

Courses	**Credits**	
	Type 1.1 Students with a master's degree	**Type 1.2** Students with a bachelor's degree
Seminars (non-credit)	4*	5*
Thesis (equivalent to)	48	72
Total credits	**48**	**72**

2. Type 2 (Thesis and additional courses)

Courses	**Credits**	
	Type 2.1 Students with a master's degree	**Type 2.2** Students with a bachelor's degree
Seminars (non-credit)	3*	4*
Required courses (non-credit)	1*	1*
Required courses	-	6
Restricted elective courses	9	15
Elective courses (no less than)	6	6
Thesis (equivalent to)	36	48
Total credits (no less than)	**51**	**75**

Note: * credits are not counted toward graduation and graded as S/U.

Curriculum courses

1. Type 1.1

1.1 Seminars (credits are not counted toward graduation and graded as S/U) 4 credits

511 592	Discussion in Mathematics	1*(0-2-1)
511 791	Seminar in Advanced Mathematics I	1*(0-2-1)
511 792	Seminar in Advanced Mathematics II	1*(0-2-1)
511 793	Seminar in Advanced Mathematics III	1*(0-2-1)

Students must register for 511 592 Discussion in Mathematics in every semester until they graduate.

Note: Courses with an asterisk " * " are required courses whose credits are not counted toward graduation and graded as S/U.

1.2 Thesis (equivalent to) 48 credits

511 891	Thesis	equivalent to 48 credits

2. Type 1.2

2.1 Seminars (credits are not counted toward graduation and graded as S/U) 5 credits

511 592	Discussion in Mathematics	1*(0-2-1)
511 791	Seminar in Advanced Mathematics I	1*(0-2-1)
511 792	Seminar in Advanced Mathematics II	1*(0-2-1)
511 793	Seminar in Advanced Mathematics III	1*(0-2-1)
511 794	Seminar in Advanced Mathematics IV	1*(0-2-1)

Students must register for 511 592 Discussion in Mathematics in every semester until they graduate.

2.2 Thesis (equivalent to) 72 credits

511 892	Thesis	equivalent to 72 credits

3. Type 2.1

3.1 Seminars (credits are not counted toward graduation and graded as S/U) 3 credits

511 592	Discussion in Mathematics	1*(0-2-1)
511 791	Seminar in Advanced Mathematics I	1*(0-2-1)
511 792	Seminar in Advanced Mathematics II	1*(0-2-1)

Students must register for 511 592 Discussion in Mathematics in every semester until they graduate.

3.2 Required courses (credits are not counted toward graduation and graded as S/U) 1 credit

511 585	Computer Tools for Mathematics Students	1*(0-2-1)

3.3 Restricted elective courses

Students are required to earn 9 credits of restricted elective courses.

511 512	Abstract Algebra I	3(3-0-6)
511 513	Abstract Algebra II	3(3-0-6)
511 515	Advanced Linear Algebra	3(3-0-6)
511 516	Universal Algebra	3(3-0-6)
511 517	Algebraic Coding Theory	3(3-0-6)
511 522	Real Analysis I	3(3-0-6)
511 523	Real Analysis II	3(3-0-6)
511 524	Functional Analysis	3(3-0-6)
511 525	Complex Analysis	3(3-0-6)
511 531	Topology	3(3-0-6)

Note: Courses with an asterisk " * " are required courses whose credits are not counted toward graduation and graded as S/U.

511 532	Differentiable Manifolds	3(3-0-6)
511 534	Algebraic Geometry	3(3-0-6)
511 541	Analytic Number Theory	3(3-0-6)
511 551	Combinatorics	3(3-0-6)
511 552	Graph Theory	3(3-0-6)
511 561	Theory of Ordinary Differential Equations	3(3-0-6)
511 562	Partial Differential Equations	3(3-0-6)
511 572	Numerical Analysis	3(3-0-6)
511 576	Probability Theory	3(3-0-6)
511 577	Stochastic Processes	3(3-0-6)

3.4 Elective courses

Students are required to earn at least 6 credits of elective courses. Students can select courses from the following list, from the restricted elective courses, or from the new courses that the department will approve later.

511 533	Lie Groups and Lie Algebras	3(3-0-6)
511 553	Advanced Combinatorics	3(3-0-6)
511 571	Mathematical Modeling	3(3-0-6)
511 573	Mathematical Theory of Inverse Problems	3(3-0-6)
511 574	Numerical Methods for Partial Differential Equations	3(3-0-6)
511 575	Financial Mathematics	3(3-0-6)
511 581	Multigrid Techniques for Differential Equations	3(3-0-6)
511 582	Numerical Methods for Image Registration	3(3-0-6)
511 583	Variational Techniques and Partial Differential Equations in Image Processing	3(3-0-6)
511 584	Optimization	3(3-0-6)
511 701	Selected Topics in Mathematics I	3(3-0-6)
511 702	Selected Topics in Mathematics II	3(3-0-6)
511 711	Selected Topics in Algebra	3(3-0-6)
511 712	Selected Topics in Coding Theory	3(3-0-6)
511 721	Selected Topics in Analysis	3(3-0-6)
511 731	Selected Topics in Geometry	3(3-0-6)
511 741	Selected Topics in Number Theory	3(3-0-6)
511 751	Selected Topics in Combinatorics	3(3-0-6)
511 752	Selected Topics in Graph Theory	3(3-0-6)
511 761	Selected Topics in Differential Equations	3(3-0-6)
511 771	Selected Topics in Applied Mathematics	3(3-0-6)
511 781	Selected Topics in Computational Science	3(3-0-6)
511 782	Selected Topics in Optimization	3(3-0-6)

3.5 Thesis (equivalent to) 36 credits

511 893	Thesis	equivalent to 36 credits

4. Type 2.2

4.1 Seminars (credits are not counted toward graduation and graded as S/U) 4 credits

511 592	Discussion in Mathematics	1*(0-2-1)
511 791	Seminar in Advanced Mathematics I	1*(0-2-1)
511 792	Seminar in Advanced Mathematics II	1*(0-2-1)
511 793	Seminar in Advanced Mathematics III	1*(0-2-1)

Students must register for 511 592 Discussion in Mathematics in every semester until they graduate.

4.2 Required courses (credits are not counted toward graduation and graded as S/U) 1 credit

511 585	Computer Tools for Mathematics Students	1*(0-2-1)

4.3 Required courses 6 credits

511 514	Linear Algebra with Applications	3(3-0-6)
511 521	Mathematical Analysis	3(3-0-6)

4.4 Restricted elective courses

Students are required to earn 15 credits of restricted elective courses. Students must enroll in at least two courses from two different groups of the three groups below:

Algebra

511 512	Abstract Algebra I	3(3-0-6)
511 513	Abstract Algebra II	3(3-0-6)
511 515	Advanced Linear Algebra	3(3-0-6)

Analysis

511 522	Real Analysis I	3(3-0-6)
511 524	Functional Analysis	3(3-0-6)
511 525	Complex Analysis	3(3-0-6)

Applied Mathematics

511 561	Theory of Ordinary Differential Equations	3(3-0-6)
511 562	Partial Differential Equations	3(3-0-6)
511 572	Numerical Analysis	3(3-0-6)

In addition, students can enroll in the following courses:

511 516	Universal Algebra	3(3-0-6)
511 517	Algebraic Coding Theory	3(3-0-6)
511 523	Real Analysis II	3(3-0-6)
511 531	Topology	3(3-0-6)
511 532	Differentiable Manifolds	3(3-0-6)

Note: Courses with an asterisk " * " are required courses whose credits are not counted toward graduation and graded as S/U.

511 534	Algebraic Geometry	3(3-0-6)
511 541	Analytic Number Theory	3(3-0-6)
511 551	Combinatorics	3(3-0-6)
511 552	Graph Theory	3(3-0-6)
511 576	Probability Theory	3(3-0-6)
511 577	Stochastic Processes	3(3-0-6)

4.5 Elective courses

Students are required to earn at least 6 credits of elective courses. Students can select courses from the following list, from the restricted elective courses, or from the new courses that the department will approve later.

511 533	Lie Groups and Lie Algebras	3(3-0-6)
511 553	Advanced Combinatorics	3(3-0-6)
511 571	Mathematical Modeling	3(3-0-6)
511 573	Mathematical Theory of Inverse Problems	3(3-0-6)
511 574	Numerical Methods for Partial Differential Equations	3(3-0-6)
511 575	Financial Mathematics	3(3-0-6)
511 581	Multigrid Techniques for Differential Equations	3(3-0-6)
511 582	Numerical Methods for Image Registration	3(3-0-6)
511 583	Variational Techniques and Partial Differential Equations in Image Processing	3(3-0-6)
511 584	Optimization	3(3-0-6)
511 701	Selected Topics in Mathematics I	3(3-0-6)
511 702	Selected Topics in Mathematics II	3(3-0-6)
511 711	Selected Topics in Algebra	3(3-0-6)
511 712	Selected Topics in Coding Theory	3(3-0-6)
511 721	Selected Topics in Analysis	3(3-0-6)
511 731	Selected Topics in Geometry	3(3-0-6)
511 741	Selected Topics in Number Theory	3(3-0-6)
511 751	Selected Topics in Combinatorics	3(3-0-6)
511 752	Selected Topics in Graph Theory	3(3-0-6)
511 761	Selected Topics in Differential Equations	3(3-0-6)
511 771	Selected Topics in Applied Mathematics	3(3-0-6)
511 781	Selected Topics in Computational Science	3(3-0-6)
511 782	Selected Topics in Optimization	3(3-0-6)

4.6 Thesis (equivalent to) 48 credits

511 891	Thesis	equivalent to 48 credits

Course Descriptions

511 512 Abstract Algebra I 3(3-0-6)

Groups. Group actions. Sylow theorems and applications. Finite abelian groups. Basic properties of rings. Unique factorization domains. Polynomial rings. Fields and field extensions.

511 513 Abstract Algebra II 3(3-0-6)

Prerequisite: 511 512 Abstract Algebra I
or with the approval of the department

Jordan-Hölder theorem. Solvable groups. Classification of field extensions: algebraic, transcendental, normal and separable extensions. Galois theory. Modules.

511 514 Linear Algebra with Applications 3(3-0-6)

Vector spaces. Linear transformations. Linear functionals. Diagonalization. Jordan canonical forms. Inner product spaces. Orthonormal basis. Spectral decomposition. Applications.

511 515 Advanced Linear Algebra 3(3-0-6)

Prerequisite: 511 514 Linear Algebra with Applications
or with the approval of the department

Rigorous treatment of linear algebra. Quotient spaces. Dual spaces. Cayley-Hamilton theorem and minimal polynomials. Canonical forms. Bilinear, quadratic and Hermitian forms. Multilinear functions and tensor products.

511 516 Universal Algebra 3(3-0-6)

Prerequisite: 511 512 Abstract Algebra I
or with the approval of the department

Lattices and orders. The elements of universal algebra. Birkhoff's subdirect representation theorem. Free algebra. Equational classes and Birkhoff's variety theorem. Mal'cev-type conditions. Selected topics of interest.

511 517 Algebraic Coding Theory 3(3-0-6)

Prerequisite: 511 512 Abstract Algebra I
or with the approval of the department

Error detection and correction. Encoding and decoding. Finite fields. Linear codes. Cyclic and BCH codes. Weight-distributions. Bounds in coding theory and constructions of Codes. Self-orthogonal codes, self-dual codes, complementary dual codes and applications.

511 521 Mathematical Analysis 3(3-0-6)

Real number system. Metric and topological spaces. Sequences. Series. Continuous functions. Derivatives. Riemann integrals. Sequences and series of functions.

511 522 Real Analysis I 3(3-0-6)

Algebras of sets. Outer measure. Lebesgue measure. Lebesgue Measurable functions. Riemann and Lebesgue integrals. Differentiation and integration. L^p spaces.

511 523 Real Analysis II 3(3-0-6)

Prerequisite: 511 522 Real Analysis I
or with the approval of the department

Abstract measure spaces. Measurable functions. Integration. Modes of convergence. Product measures. Abstract L^p spaces.

511 524 Functional Analysis 3(3-0-6)

Normed spaces. Banach spaces. Bounded linear operators and functionals. Open mapping theorem. Closed graph theorem. Uniform boundedness principle. Hahn-Banach extension theorem. Inner product spaces. Hilbert spaces. Orthogonality. Riesz representation theorem. Adjoint operators. Compact operators.

511 525 Complex Analysis 3(3-0-6)

Analytic functions. Complex integration. Cauchy's theorem and applications. Singularities. Residues and applications. Maximum principles. Normal families and Montel's theorem. Riemann's mapping theorem. Harmonic functions.

511 531 Topology 3(3-0-6)

Topological spaces. Compact and locally compact spaces. Connected and locally connected spaces. Countability axioms. Separability axioms. Product spaces. Topology of the plane. Euclidean spaces.

511 532 Differentiable Manifolds 3(3-0-6)

Manifolds and submanifolds. Immersions, embeddings, and submersions. Tangent bundles and tangent maps. Vector fields. Derivations. Sard's theorem. Tensors. Differential forms.

511 533 Lie Groups and Lie Algebras 3(3-0-6)

Prerequisite: 511 532 Differentiable Manifolds
or with the approval of the department

Lie groups. Lie algebras. Lie algebra of a Lie group. Relationships between Lie groups and Lie algebras. Introduction to representation.

511 534 Algebraic Geometry 3(3-0-6)

Prerequisite: 511 513 Abstract Algebra II
or with the approval of the department

Algebraic varieties. Sheaves. Projective varieties. Group law on a plane cubic curve. Tangent space of an affine and a projective variety. Projective embeddings. Riemann-Roch theorem.

511 541 Analytic Number Theory 3(3-0-6)

Arithmetic functions. Dirichlet series. Riemann zeta function. L-functions. Dirichlet's theorem. The prime number theorem.

511 551 Combinatorics 3(3-0-6)

The pigeonhole principle and Ramsey's theorem. Generating functions. Recurrence relations. The inclusion-exclusion principle. Pólya's theorem. Block designs.

511 552 Graph Theory 3(3-0-6)

Graphs and subgraphs. Trees. Connectivity. Matchings and factorization of graph. Eulerian graphs. Hamiltonian graphs. Planar graphs. Colorings and the four-color theorem.

511 553 Advanced Combinatorics 3(3-0-6)

(0,1)-matrices. Latin squares. Hadamard matrices. Young tableaux. Strongly regular graphs. Designs. Combinatorial games.

511 561 Theory of Ordinary Differential Equations 3(3-0-6)

Linear systems of first order ordinary differential equations. Phase line diagram. Linear systems. Vector and matrix equations. Stability of linear systems. Floquet theory. Autonomous systems. Phase plane diagrams. Phase plane diagram for linear systems. Stability for nonlinear autonomous systems. Lyapunov functions. Stability theorem.

511 562 Partial Differential Equations 3(3-0-6)

First and second order partial differential equations. Elliptic, hyperbolic, and parabolic equations. Existence and uniqueness of solutions. Maximum principles and energy methods. Methods of solving partial differential equations on bounded and unbounded domains. Weak solutions. Sobolev spaces.

511 571 Mathematical Modeling 3(3-0-6)

Mathematical concept in a modeling frame work. Practical problems chosen from common experiences encompassing many academic disciplines. Implementations of analytical and numerical analysis with the use of mathematical tool. Evaluation of mathematical model or real data.

511 572 Numerical Analysis 3(3-0-6)

Accuracy of approximations. Interpolations. Analysis of linear and nonlinear system. Analysis of numerical differentiations and integrations. Analysis of numerical solutions of ordinary differential equations and partial differential equations.

511 573 Mathematical Theory of Inverse Problems 3(3-0-6)

Fundamental properties of an ill-posed inverse problem. Basic theorems for the construction and analysis of regularization methods. General theory of regularization. Classical regularization methods. Truncated singular value decomposition. Tikhonov and iterative regularization methods. Projection methods.

511 574 Numerical Methods for Partial Differential Equations 3(3-0-6)

Basic concept of mathematical techniques for initial and boundary value problems in partial differential equations. Finite difference and finite element discretization techniques for parabolic, hyperbolic, and elliptic problems. Direct and iterative methods for discrete problems. Cases studies.

511 575 Financial Mathematics 3(3-0-6)

Interest rates. Time value of money. Stock and bonds. Other securities. Simple financial market model. Risk-free assets. Risky assets. Discrete time market models. Portfolio management. Derivatives. Applications.

511 576 Probability Theory 3(3-0-6)

Condition: only with the approval of the department

Probability space. Axiomatic theory of probability. Random variables. Independence of random variables. Distribution functions. Expectations. Moment generating functions. Characteristic functions. Convergence of random variables. Weak and strong laws of large numbers. Central limit theorem.

511 577 Stochastic Processes 3(3-0-6)

Condition: only with the approval of the department

Random variables and probability distribution functions. Conditional Expectation. Martingales. Markov chains. Poisson processes. Renewal theory. Random walks. Brownian motion. Applications of stochastic process.

511 581 Multigrid Techniques for Differential Equations 3(3-0-6)

Finite difference methods for ordinary and partial differential equations. Basic iterative methods for finite difference equations. Basic idea and theory of multigrid methods. Nonlinear multigrid method. Selected applications.

511 582 Numerical Methods for Image Registration 3(3-0-6)

Basic concepts of image registration. Mathematical modeling of image registration. Similarity measures. Parametric and non-parametric image registration. Variational techniques. Regularization techniques for image registration. Numerical methods for elastic-based, diffusion-based, and curvature-based image registration.

511 583 Variational Techniques and Partial Differential Equations in Image Processing **3(3-0-6)**

Basic concepts of mathematical image processing. Variational techniques for image processing. Sobolev space and the space of functions of bounded variation. Image denoising. Image deblurring. Image inpainting. Image segmentation. Optical flow computation. Image registration.

511 584 Optimization **3(3-0-6)**

Basic concepts of optimization. One-dimensional search methods. Gradient methods. Newton's method. Conjugate direction methods. Quasi-Newton methods. Global search algorithms. Theory of constrained optimization. Algorithms for constrained optimizations. Selected applications.

511 585 Computer Tools for Mathematics Students **1(0-2-1)**

Condition: Graded as S or U

Mathematical document creation. Concepts and techniques of presentation. Tools for solving mathematical problems.

511 592 Discussion in Mathematics **1(0-2-1)**

Condition: Graded as S or U

Discussion on topics of interest in mathematics.

511 701 Selected Topics in Mathematics I **3(3-0-6)**

Condition: only with the approval of the department

Selected topics in mathematics relevant and complementary to current research and topics of current interest.

511 702 Selected Topics in Mathematics II **3(3-0-6)**

Condition: only with the approval of the department

Selected topics in mathematics relevant and complementary to current research and topics of current interest.

511 711 Selected Topics in Algebra **3(3-0-6)**

Condition: only with the approval of the department

Selected topics in advanced algebra relevant and complementary to current research and topics of current interest.

511 712 Selected Topics in Coding Theory **3(3-0-6)**

Condition: only with the approval of the department

Selected topics in coding theory relevant and complementary to current research and topics of current interest.

511 721 Selected Topics in Analysis 3(3-0-6)

Condition: only with the approval of the department

Selected topics in advanced analysis relevant and complementary to current research and topics of current interest.

511 731 Selected Topics in Geometry 3(3-0-6)

Condition: only with the approval of the department

Selected topics in geometry relevant and complementary to current research and topics of current interest.

511 741 Selected Topics in Number Theory 3(3-0-6)

Condition: only with the approval of the department

Selected topics in number theory relevant and complementary to current research and topics of current interest.

511 751 Selected Topics in Combinatorics 3(3-0-6)

Condition: only with the approval of the department

Selected topics in combinatorics relevant and complementary to current research and topics of current interest.

511 752 Selected Topics in Graph Theory 3(3-0-6)

Condition: only with the approval of the department

Selected topics in advanced graph theory relevant and complementary to current research and topics of current interest.

511 761 Selected Topics in Differential Equations 3(3-0-6)

Condition: only with the approval of the department

Selected topics in differential equations relevant and complementary to current research and topics of current interest.

511 771 Selected Topics in Applied Mathematics 3(3-0-6)

Condition: only with the approval of the department

Selected topics in applied mathematics relevant and complementary to current research and topics of current interest.

511 781 Selected Topics in Computational Science 3(3-0-6)

Condition: only with the approval of the department

Selected topics in computational science relevant and complementary to current research and topics of current interest.

511 782 Selected Topics in Optimization 3(3-0-6)

Condition: only with the approval of the department

Selected topics in optimization relevant and complementary to current research and topics of current interest.

511 791 **Seminar in Advanced Mathematics I** **1(0-2-1)**

Condition: only with the approval of the department
Graded as S or U

Seminar on current research in advanced mathematics.

511 792 **Seminar in Advanced Mathematics II** **1(0-2-1)**

Condition: only with the approval of the department
Graded as S or U

Seminar on current research in advanced mathematics.

511 793 **Seminar in Advanced Mathematics III** **1(0-2-1)**

Condition: only with the approval of the department
Graded as S or U

Seminar on current research in advanced mathematics.

511 794 **Seminar in Advanced Mathematics IV** **1(0-2-1)**

Condition: only with the approval of the department
Graded as S or U

Seminar on current research in advanced mathematics.

511 891 **Thesis** **equivalent to 48 credits**

Research topics in mathematics under the supervision of thesis advisor(s).

511 892 **Thesis** **equivalent to 72 credits**

Research topics in mathematics under the supervision of thesis advisor(s).

511 893 **Thesis** **equivalent to 36 credits**

Research topics in mathematics under the supervision of thesis advisor(s).

Graduation criteria

Graduation criteria shall be in accordance with Silpakorn University's Regulations on Graduate Study B.E. 2561 (2018), Section 8 in Appendix 1 and/or subsequent revision. The addition criterions are the following.

(1) Students may graduate after having completed a minimum of 6 semesters in programs Type 1.1 and Type 2.1, and a minimum of 8 semesters in Type 1.2 and Type 2.2.

(2) Students must submit a proof of English proficiency from a language institute at CEFR standard as specified by the university at a minimum of B2 level to the program committee. The language test shall be taken within 2 years from the start of the program and it cannot be substituted by passing courses provided by the university.

(3) The thesis in the program Type 1 must result in at least 2 publications in peer-reviewed international journals. The thesis in the program Type 2 must result in at least 1 publication in a peer-reviewed international journal. All students must give at least 1 oral presentation in an international conference.