Program: Doctor of Philosophy Program in Applied Mathematics (International Program)
Degree: Doctor of Philosophy (Applied Mathematics)
Study Plan:

1) Research Program (Scheme 1.1: for Master's Degree holder)

Year	First Trimester	Cr	Second Trimester	Cr	Third Trimester	Cr
Year 1	103999 Ph.D. Thesis	3	103891 Seminar III		103999 Ph.D. Thesis	8
			103999 Ph.D. Thesis	8		
	Total	**3**	**Total**	**8**	**Total**	**8**
Year 2	103999 Ph.D. Thesis	8	103991 Seminar IV		103999 Ph.D. Thesis	8
			103999 Ph.D. Thesis	8		
	Total	**8**	**Total**	**8**	**Total**	**8**
Year 3	103999 Ph.D. Thesis	8	103999 Ph.D. Thesis	6	103999 Ph.D. Thesis	3
	Total	**8**	**Total**	**6**	**Total**	**3**

2) Regular Program (Scheme 2.1: for Master's Degree holder)

Year	First Trimester	Cr	Second Trimester	Cr	Third Trimester	Cr
Year 1	103XXX Elective	4	103891 Seminar III	1	103999 Ph.D. Thesis	3
	103XXX Elective	4	103XXX Elective	4		
			103999 Ph.D. Thesis	3		
	Total	**8**	**Total**	**8**	**Total**	**3**
Year 2	103XXX Elective	4	103991 Seminar IV	1	103999 Ph.D. Thesis	8
	103999 Ph.D. Thesis	4	103999 Ph.D. Thesis	8		
	Total	**8**	**Total**	**9**	**Total**	**8**
Year 3	103999 Ph.D. Thesis	8	103999 Ph.D. Thesis	8	103999 Ph.D. Thesis	3
	Total	**8**	**Total**	**8**	**Total**	**3**

Program: Doctor of Philosophy Program in Applied Mathematics (International Program)
Degree: Doctor of Philosophy (Applied Mathematics)
Course Description:

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
Core Course				
103621 Functional Analysis	4(4-0-12)	Consent of the School	Normed linear spaces, Banach spaces, bounded linear operators, dual spaces, inner product spaces, Hilbert space bases, Riesz representation theorem, self-adjoint, normal and unitary operators, Hahn-Banach theorems, uniform boundedness principle, open mapping theorem, closed graph theorem, reflexive spaces, weak-and weak*-convergence.	1. explain fundamental concepts, properties and theorems of general normed linear spaces 2. explain fundamental concepts and properties and theorems of bounded linear operators on a normed linear space 3. explain fundamental concepts, properties and theorems of general Hilbert spaces and bounded linear operators on them 4. state and explain the fundamental theorems of functional analysis, including the Hahn-Banach theorem, uniform boundedness principle, open mapping theorem and closed graph theorem 5. provide examples and counterexamples relating to the major theorems in the course 6. solve theoretical and practical problems related with all of the course contents by using correct mathematical reasoning and notation.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103631	Advanced Ordinary Differential Equations	4(4-0-12)	Consent of the School	First-order differential equations, initial value problems, existence, uniqueness and continuity of solutions, the contraction principle, existence and uniqueness theorems, continuity of a solution with respect to parameters, non-extendable solution, dynamical systems, the perturbation equation, systems of linear equations, periodic systems of linear ordinary differential equations, linear equations of m-th order, and stability theory.	1. solve linear and fractional first-order ordinary differential equations 2. find domains where functions satisfy Lipschitz conditions 3. apply existence and uniqueness theorems to normal first-order systems of ordinary differential equations 4. analyze properties of solutions of initial value problems such as dependence on parameters and extension of solutions 5. apply stability analysis to linear and quasilinear systems of ordinary differential equations.
103651	Numerical Linear Algebra	4(4-0-12)	Consent of the School	Analysis and computational aspects of linear algebra and matrices by focusing on matrix factorization, systems of linear equations and iterative methods, least squares problem, eigenvalue problems.	1. explain fundamentals of floating point operations: finite precision matrix computation, floating point number models, round off analysis, 2. explain and work with fundamental concepts of linear algebra: vector-matrix operations, partitioning of a matrix, banded matrix, vector and matrix norms, 3. apply direct methods for solving linear systems of algebraic equations: Gauss elimination method, singular value decomposition, LU-factorization, 4. apply methods of factorization: Cholesky factorization, sweep and LU factorization for tridiagonal systems, Householder reflection, 5. apply iterative methods: Jacoby and Gauss-Seidel methods, SOR-methods.
Seminar Courses					

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103691 Seminar I	1(1-0-9)	None	Introduction to mathematical research methodology processes including literature search, literature review, individual study, and discussion with emphasis on communication skills through oral presentation and academic writing.	1. study a mathematical paper in depth and independently up to the level of comprehension 2. perform literature research and review of related articles 3. give a presentation related with the contents of a paper in a mathematically correct, structured and understandable way 4. answer and discuss mathematical questions related with their presentation to an audience of peers.
103791 Seminar II	1(1-0-9)	103691 Seminar I, or consent of the School	Discussion and presentation of problems of interest in mathematics or related areas, presentation of topics or research problems from the student's thesis work, together with development of presentation skills at academic conferences.	1. study a mathematics-related research paper in depth and independently up to the level of comprehension 2. perform literature research and review of related articles 3. give a presentation related with the contents of a research paper in a mathematically correct, structured and understandable way 4. use technological tools such as PowerPoint to enhance mathematical presentations 5. answer and discuss critical questions related with their presentation to an audience of peers in the English language.

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103891 Seminar III	1(1-0-9)	103791 Seminar II, or consent of the School	Presentation of problems or topics of advanced research or on the frontiers of research in mathematics or related areas, further development of academic writing skills in combination with presentation of topics or research problems from the student's thesis work.	1. study a paper of current mathematics-related research in depth and independently up to the level of comprehension 2. perform literature research and review of related articles 3. give a presentation related with the contents of a research paper in a mathematically correct, structured and understandable way 4. use technological tools such as PowerPoint to enhance oral presentations 5. answer and discuss critical questions related with the topics of their presentations to an audience of peers in the English language.
103991 Seminar IV	1(1-0-9)	103891 Seminar III, or consent of the School	Presentation of problems or issues through independent study, further enhancement of academic writing skills and presentation of thesis research.	1. study a series of paper of current mathematics-related research in depth and independently up to the level of comprehension 2. perform in-depth literature research and review of related articles 3. give a series of presentations related with the contents of a research topic in a mathematically correct, structured and understandable way 4. use technological tools such as PowerPoint to enhance oral presentations 5. answer and discuss critical questions related with the topics of their presentations to an audience of peers and specialists in the English language.
Elective Courses				

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103612	Applications of Discrete Mathematics	4(4-0-12)	Consent of the School	Discrete structures, coding theory, applications of combinatorics, block designs, Latin squares and their applications, applications of graph theory	1. explain discrete structures 2. explain coding theory, encryption and decryption 3. explain applications of combinatorics in real life 4. explain block designs, Latin square and their applications in scheduling 5. explain the applications of graph theory.
103716	Selected Topics in Algebra	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of algebra.	
103717	Selected Topics in History and Philosophy of Mathematics	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of history and philosophy of mathematics.	
103718	Selected Topics in Number Theory	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of number theory.	
103719	Selected Topics in Combinatorics	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of combinatorics.	
Analysis Course					

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103622 Measure Theory	4(4-0-12)	Consent of the School	Measurable spaces, measures, the Lebesgue integral, convergence theorems, the L^p -spaces, Radon-Nikodym theorem, Fubini's theorem, Borel measures on the real line	1. explain fundamental concepts and the main theorems related with measures, including sigma-algebras, measurable spaces and measurable functions 2. describe the Lebesgue integral and its properties, including the main relevant theorems, 3. explain the difference between Riemann and Lebesgue integral 4. describe the construction of the -spaces and their properties, including the relevant theorems 5. describe the connection between Borel measures on the line and distribution functions, 6. provide examples and counterexamples relating to the major theorems in the course 7. solve theoretical and practical problems related with all of the course contents by using correct mathematical reasoning and notation.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103623	Fourier Series and Transforms	4(4-0-12)	Consent of the School	Pointwise and L^p-convergence of Fourier series, summability methods, convolution and approximate identities, the group structure of the compact circle group and the group of real numbers as related to Fourier series and transforms, convergence and summability of Fourier transforms, the Plancherel theorem, distribution spaces, Fourier transform and convolution of distributions, discrete Fourier transform.	1. compute the Fourier series and Fourier transforms of some simple functions 2. describe the properties of the Fourier transform as a linear operator between function spaces 3. state the fundamental theorems related with the Fourier transform 4. describe conditions on existence and convergence of the inverse Fourier transform 5. describe the space of tempered distributions, its properties, and the Fourier transform on it 6. explain the concepts of the discrete Fourier transform and the fast Fourier transform, and express them in matrix form. 7. solve theoretical and practical problems related with the course contents by using correct mathematical reasoning and notation.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103624	Probability and Random Process	4(4-0-12)	103622 Measure Theory, or consent of the School	Graduate introduction to probability theory by including topics on: probability spaces, random variables, distributions, conditional expectation, law of large numbers, central limit theorem, stochastic processes, filtrations, Poisson random measures, Brownian motion and martingales.	1. explain the concept of probability space 2. explain the concept of random variable and classify the types of the random variables 3. explain the concept and calculate conditional probability 4. state the law of large numbers and central limit theorem 5. explain the concept of stochastic processes and filtrations 6. explain the concept of Poisson random measures 7. explain the concept and the main properties of Brownian motion including martingales.
103721	Stochastic Analysis	4(4-0-12)	103622 Measure Theory, or consent of the School	Construction of stochastic processes, martingale and stopping time, Brownian motion, stochastic integration with respect to Brownian motion, Girsanov's theorem, local time of Brownian motion, Markov property for Ito diffusions, stochastic differential equations, stochastic control.	1. explain the concept of construction of stochastic processes 2. explain the concept of martingale, stopping time and Brownian motion 3. explain the method of stochastic integration with respect to Brownian motion 4. state the Girsanov theorem 5. explain the Markov property for Ito diffusions 6. explain the concept of stochastic differential equations and stochastic control.
103729	Selected Topics in Analysis	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of analysis.	
103828	Advanced Topics in Functional Analysis	4(4-0-12)	Consent of the School	Advanced content according to students' interests, requirements and current trends in the field of functional analysis.	

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103829	Advanced Topics in Analysis	4(4-0-12)	Consent of the School	Advanced content according to students' interests, requirements and current trends in the field of analysis.	
Differential Equations Course					
103632	Principles of Partial Differential Equations	4(4-0-12)	Consent of the School	Basic definitions and examples, first-order PDEs, the Cauchy problem, method of characteristics, quasilinear, first order PDEs, quasilinear systems of PDEs, Cauchy problem, hyperbolic systems of quasilinear first order equations, linear second-order PDEs, well-posed problems, elliptic equations, maximum principles, harmonic functions, solution of the Dirichlet problem on a ball, subharmonic functions, Ascoli-Arzela theorem, theorem of existence of solutions to a Dirichlet problem, properties of parabolic equations, Dirichlet and Neumann problems.	1. use the method of characteristics for a solving a first-order partial differential equation with a single unknown function 2. construct appropriate conditions on the surface where a solution has a discontinuity 3. find characteristics of a system of partial differential equations and conditions on them 4. formulate a non-characteristic initial value problem for a system of quasilinear partial differential equations 5. find domains of uniqueness of a solution of initial value problems for a hyperbolic linear system of first-order equations 6. use weak and strong maximum principles for analysis of an elliptic second-order PDE 7. formulate and analyze Dirichlet and von-Neumann problems.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103731	Group Analysis of Differential Equations	4(4-0-12)	Consent of the School	Group of scale transformations, self-similar solutions, one-parameter local Lie groups of transformations, invariants and invariant manifolds of a group, prolongation of a Lie group, Lie algebra of operators, optimal system of subalgebras, equivalence transformations, group classification of differential equations, multi-parameter groups, invariant and partially invariant solutions of PDEs, Lie-Backlund symmetries, contact transformations of finite order, symmetry and conservation laws, Noether's theorem.	1. explain fundamentals of Lie groups and Lie algebras: vector space of generators and classification of Lie algebras 2. explain and work with fundamental concepts of Lie group of transformations and their applications to PDEs: admitted Lie group and equivalence Lie group 3. apply the group analysis method to PDEs for finding admitted Lie groups and the classification of PDEs with respect to admitted Lie groups 4. apply the group analysis method for finding invariant and partially invariant solutions of PDEs 5. explain fundamentals of Lie-Backlund symmetries and relations between Lie-Backlund symmetries and conservation laws of PDEs.
103739	Selected Topics in Differential Equations	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of differential equations.	
103839	Advanced Topics in Differential Equations	4(4-0-12)	Consent of the School	Advanced content according to students' interests, requirements and current trends in the field of differential equations.	
Financial Mathametic Course					
103641	Time Series Analysis and Forecasting	4(4-0-12)	Consent of the School	Statistics background for forecasting, regression analysis and forecasting, exponential smoothing methods, ARIMA models, transfer functions and intervention models.	1. explain the concepts and methods of simple and multiple regression 2. explain and compute the forecasts using the exponential smoothing method 3. explain and compute the forecasts using the ARIMA models 4. explain the concept of transfer function and intervention models.

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103642 Statistical Inference	4(4-0-12)	Consent of the School	Families of distributions; desired properties of statistics and of estimators; point estimation and methods of estimation; some statistical theorems, lower bound of unbiased estimator; interval estimation and concept of hypothesis testing, Neymann – Pearson lemma, most power and uniformly most powerful test	1. explain the concept of family of distributions 2. explain the desired properties of statistic and of estimator 3. find the point estimation and explain the methods of estimation 4. explain some statistical theorems: lower bound of unbiased estimator, interval estimation and concept of hypothesis testing 5. find the critical region and most power and uniformly most powerful test with significance for testing the hypothesis.
103643 Operations Research	4(4-0-12)	Consent of the School	Linear programming, transportation models, dynamic programming, inventory models and queueing models.	1. explain the concept of linear programming 2. formulate and analyze linear programming problems 3. build and solve transportation models 4. explain the concept of dynamic programming 5. formulate and analyze problems with inventory models 6. formulate and analyze problems with queueing models.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103741	Mathematics of Financial Derivatives	4(4-0-12)	Consent of the School	Introduction to arbitrage-based pricing of derivative securities, including the topics on arbitrage, risk-neutral valuation, the log-normal hypothesis, binomial trees, the Black-Scholes formula and applications, the Black-Scholes partial differential equation, American options, one-factor interest rate models, swaps, caps, floors, and other interest-based derivatives, credit, risk and credit derivatives.	1. explain the concepts of arbitrage and risk-neutral valuation 2. explain the concepts of log-normal hypothesis and binomial trees 3. state the formula of the Black-Scholes formula and apply it 4. explain the concept of the Black-Scholes partial differential equation 5. explain the concepts of American options, one-factor interest rate models, swaps, caps, floors 6. explain the concepts of other interest-based derivatives 7. explain the concepts of credit, risk and credit derivatives.
103743	Continuous Models in Finance	4(4-0-12)	103741 Mathematics of Financial Derivatives, or consent of the School	A second course in arbitrage-based pricing of derivative securities. The Black-Scholes model and its generalizations: equivalent martingale measures, the martingale representation theorem, the market price of risk, applications including change of numeraire and the analysis of quantos. Interest rate models: the Heath-Jarrow-Morton approach and its relation to short-rate models. The volatility smile/skew and approaches to accounting for it: underlyings with jumps, local volatility models, and stochastic volatility models.	1. explain the concept of the Black-Scholes model and its generalizations 2. explain the concept of the equivalent martingale measures and the martingale representation theorem 3. explain the concept of the market price of risk, applications including change of numeraire and the analysis of quantos 4. explain the concept of interest rate models: the Heath-Jarrow-Morton approach and its relation to short-rate models 5. explain the concept of the volatility smile/skew and approaches to accounting for it: underlyings with jumps, local volatility models, and stochastic volatility models.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103748	Selected Topics in Probability	4(4-0-12)	103741 Mathematics of Financial Derivatives, or consent of the School	Content according to students' interests, requirements and current trends in the field of probability.	
103749	Selected Topics in Statistics	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of statistics.	
103848	Advanced Topics in Mathematics of Finance	4(4-0-12)	Consent of the School	Advanced content according to students' interests, requirements and current trends in the field of mathematics of finance.	
Numerical Analysis and Computer Course					
103652	Computer Tools for Mathematical Research	4(4-0-12)	Consent of the School	Aspects of computers used in mathematical research, including the Unix operating system and networking, electronic resources for mathematical research, mathematical document preparation, computer programming, symbolic computation, programming with advanced numerical libraries, and graphics.	1. perform online literature search, 2. prepare mathematical documents using the LaTeX typesetting system, 3. use symbolic mathematical software for symbolic and numerical computations, graphing and animation, 4. write a computer program for numerical computation and graphing with the help of standard numerical and graphic libraries, 5. execute common commands on a Unix/Linux terminal on the command line.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103653	Numerical Methods for Solving Partial Differential Equations	4(4-0-12)	Consent of the School	The essential roles of numerical methods, types of partial differential equations; parabolic, elliptic, and hyperbolic, finite difference method, finite element method, boundary element method, numerical solution to some boundary value-problems.	1. show understanding of the role of numerical methods in general science and engineering contexts 2. show understanding of the main concept of some conventional numerical methods such as finite difference, finite element and boundary element methods for the solution of differential equations 3. demonstrate the procedure of applying various numerical methods to selected PDEs 4. numerically find solutions to some boundary vale-problems 5. identify the advantages and disadvantages of the various numerical methods under different contexts.
103654	Finite Element Method	4(4-0-12)	Consent of the School	Basic concepts of finite element methods, formulation of finite element methods by direct methods, formulation of finite element methods by weighted residual method, element interpolation functions and numerical integration over elements, applications to some basic PDEs.	1. show understanding of the concept and significance of the finite element method (FEM) 2. show understanding of direct and formal (basic energy and weighted residual) methods for deriving finite element equations 3. formulate the system of linear equations resulted from the construction of the method, 4. perform numerical integration over elements 5. numerically apply the FEM to some selected forms of PDEs in 2 dimensions.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103655	Applied Numerical Analysis	4(4-0-12)	Consent of the School	Error analysis, solutions of systems of linear equations, solutions of nonlinear equations, interpolations, least square approximation, numerical differentiation and integration, numerical solutions of some ordinary and partial differential equations.	1. state the definitions of error types with examples 2. perform, both numerically and analytically, processes of finding solutions to nonlinear equations, and systems of linear equations 3. compute some interpolation problems, and least square approximation 4. demonstrate the process of numerically approximating differentiation and integration 5. apply some numerical methods for solving given problems of ODEs or PDEs.
103656	Collocation Meshless Method	4(4-0-12)	Consent of the School	Linear systems of equations and solving methods, data interpolation in 1 dimension, scattered data interpolation using Lagrange polynomials, radial basis function, data interpolation using radial basis function, approximation of derivatives using radial basis function, applications to ODE and PDEs, further important factors for considerations with the collocation method.	1. numerically solve some simple linear systems of equations 2. show understanding of the concepts and importance of interpolation methods of data 3. compute interpolation of given data using Lagrange polynomials 4. show understanding of the behavior and properties of radial basis functions 5. perform interpolation using radial basis functions 6. approximate the values of derivatives of functions using the concept of collocation with radial basis functions 7. apply the collocation method with radial basis functions to some differential equations 8. show understanding of the advantages and disadvantages of the methods.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103758	Selected Topics in Numerical Analysis	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of numerical analysis.	
103858	Advanced Topics in Numerical Analysis	4(4-0-12)	Consent of the School	Advanced content according to students' interests, requirements and current trends in the field of numerical analysis.	
Mathematical Modelling Course					
103761	Continuum Mechanics	4(4-0-12)	Consent of the School	Analysis of stress and deformation at a point and the derivation of the fundamental equations by applying the basic laws of conservation of mass, energy, and momentum and those of thermodynamics; development of relationships (constitutive laws) between stress, strain, and strain rate; basic equations governing the behavior of any continuum and applications to solids and fluids.	1. use fundamental algebraic properties of tensors 2. operate with tensor coordinates 3. apply tensor calculus, such as covariant derivatives of first and second orders, and their representations in various coordinate systems 4. use curvilinear coordinate systems, in particular, cylindrical and spherical coordinate systems 5. formulate conservation laws of used in continuum mechanics 6. apply elements of mathematical thermodynamics 7. derive mathematical models from the main principles of continuum mechanics.

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103762	Classical Models of Continuum Mechanics	4(4-0-12)	103761 Continuum Mechanics, or consent of the School	This is a continuing course from Continuum Mechanics (103761). Topics include: liquid and gas, particular models, dissipative processes, deformation of solids, and linear elasticity theory.	1. explain fundamentals of the gas dynamics equations: integral conservation laws and their differential forms 2. apply the integral form of conservation laws for constructing Rankine-Hugoniot conditions; 3. explain Riemann waves and Prandtl-Meyer solutions 4. explain and work with self-similar solutions of one-dimensional gas dynamics equations for constructing exact solutions of decay of arbitrary discontinuity problems 5. explain fundamentals of linear elasticity theory.
103763	Mathematical Principles of Fluid Mechanics	4(4-0-12)	103761 Continuum Mechanics, or consent of the School	Equations of motion, Stokes' axioms, Euler equations, energy equation, entropy, enthalpy, and temperature, ideal incompressible fluid, ideal inviscid and viscid fluid dynamics equations, compressible Navier-Stokes equations.	1. explain fundamentals of fluid mechanics: Stokes' axioms and derivation of the fluid dynamics equations 2. explain concepts of inviscid fluid dynamics: Euler equations and their properties 3. explain viscid incompressible fluid dynamics equations (Navier-Stokes equations) 4. construct particular solutions (Couette flow, Poiseuille flow) and their applications 5. apply a priori estimates to the Navier-Stokes equations.
103768	Selected Topics in Signal Processing	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of signal processing.	
103868	Advanced Topics in Signal Processing	4(4-0-12)	Consent of the School	Advanced content according to students' interests, requirements and current trends in the field of signal processing.	

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
Insurance Course				
103772 Life Insurance Mathematics	4(4-0-12)	Consent of the School	Basic concepts of life insurance: life annuities, benefit premiums, benefit reserves. Stochastic models for life insurance mathematics: Markov models, stochastic processes for interest rates and demography, cash flows and reserves, cover capital and Thiele's differential equation, Hattendorff's theorem, and unit-link policies.	1. explain the concept of life insurance 2. explain and compute Life Annuities, benefit premiums and benefit reserves 3. explain the stochastic models for life insurance, Markov models, stochastic processes for interest rates and demography 4. explain and compute the cash flows and reserves, cover capital and Thiele's differential equation 5. explain Hattendorff's theorem and unit-link policies.
Other Mathematic Course				
103787 Selected Topics in Geometry	4(4-0-12)	Consent of the School	Content according to students' interests, requirements and current trends in the field of geometry.	
103788 Selected Topics in Mathematics in Modern Technology	4(4-0-12)	Consent of the School	This course covers topics in the development and application of modern technology. Contents is according to students' interests and requirements and the current trends in research and development relating mathematics and modern technology.	
103789 Selected Topics in Applied Mathematics	4(4-0-12)	Consent of the School	This course covers topics in the field of applied mathematics. Content is according to students' interests, requirements and current trends in research and development of applied mathematics.	

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
103888	Advanced Topics in Mathematics in Modern Technology	4(4-0-12)	Consent of the School	This course covers advanced topics in the development and application of modern technology. Contents is according to students' interests and requirements and the current trends in research and development relating mathematics and modern technology.	
103889	Advanced Topics in Applied Mathematics	4(4-0-12)	Consent of the School	This course covers advanced topics in the field of applied mathematics. Content is according to students' interests, requirements and current trends in research and development of applied mathematics.	
Thesis Course					
103999	Ph.D. Thesis			High quality thesis research, generating new knowledge, academic and professional advancement.	1. prepare a research proposal on a mathematical topic 2. review contemporary scientific research literature 3. conduct in-depth research on a topic in mathematics generating new knowledge beyond the current frontier in the field 4. write a thesis in the English language which presents the details and results of their research work in logical, complete and clear manner 5. communicate the results of their research work in the English language to an audience of specialists in the field through an oral presentation, correctly answer critical and detailed questions related to the field of research and their own research work to an audience of specialists in the field in an oral presentation.
Elective Course from Other School					

Courses	Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
204646 Data Management Technology	3(3-0-6)	None	Concepts and theories in data management; database architecture; relational database; relational database model; logical database design with normalization; physical database design; database applications in information work; languages in data query and management; transaction management; data security; modern data management such as Big Data and NoSQL.	
204647 Data Security	3(3-0-6)	None	Concepts of data security; problems caused by human and systems: computer crime and ethics; data vulnerability; security management and access control; technologies and tools for data security; computer network control, intrusion prevention, biometrics control; cryptography: encryption and decryption, private keys and public keys, digital signature, etc.; legal and ethical issues in data security, trends of data security and its applications.	
204648 Data Analytics	3(3-0-6)	None	Principles of data analysis; data warehouse; online analytical processing (OLAP); knowledge discovery in database; data mining; processes and techniques of data classification; processes and techniques of data clustering; processes of association rule discovery; data mining tools and technologies; data mining evaluation; related research in data analytics.	

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
204903	Selected Topics in Artificial Intelligence	3(3-0-6)	None	Principles of artificial intelligence, Its scope, history and techniques; knowledge representation; memory structures; reasoning mechanisms, probabilistic reasoning and searching techniques; games; planning; artificial intelligence-related research: machines learning; evolutionary computation; natural language processing; introduction to fuzzy logic; expert systems.	
204908	Selected Topics in High Performance Computing	3(3-0-6)	None	Concept and related research in high performance computing: High performance computing architecture; virtualization, grid and cloud technologies; MPI programming; MPI/IO programming; OpenMP programming; Multi-thread programming; designing a parallel program; performance modeling; GPU programming; distributed programming; development and debugging tools.	
205501	Entrepreneurship and Innovation	2(2-0-4)	None	Study of entrepreneurship, innovation and technology business, open innovation, attitudes and motivation of innovative entrepreneurs and social entrepreneurs, characteristics of successful entrepreneurs, new venture process, business model generation and business plan, business Frost & Sullivan feasibility and problems of new ventures.	

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
205502	Opportunity and Feasibility Analysis	2(2-0-4)	None	Identify potential opportunities, trend and market analysis, technology roadmap and forecasting, opportunity assessment, develop a business concept and vision, customer's insight and customer validation, and feasibility analysis.	
205503	Intellectual Property Strategies	2(2-0-4)	None	Concepts and principles of intellectual property management, intellectual property from research and development, patent searching, intellectual property laws and methods of intellectual property protection, intellectual property valuation and method in creating return on intellectual properties.	
205506	Business Models and Strategies for New Venture	3(3-0-6)	None	Business model and strategic management concept, business environmental analysis, business lifecycles, analyzing existing business models, developing a business model for a new startup venture, and testing business model building block, formulating strategies for new venture, and internationalization strategies.	
205507	Entrepreneurial Marketing	3(3-0-6)	None	Marketing for new products and new markets, market opportunity analysis and evaluation, market segmentation strategies, value proposition design, marketing strategies and marketing plan, the use of internet in marketing, new product launch, branding and brand management, and marketing metrics.	

Courses		Credit (Lect.-Lab-Self stud.)	Prerequisite	Course Description	Expected Learning Outcomes
205508	Entrepreneurial Finance	3(3-0-6)	None	Principles of entrepreneurship, financing for entrepreneurial processes from start-up to harvesting, cost structure and financing need analysis, revenue model analysis, financing from money and capital markets, analysis and evaluation of financing sources, and cash flow analysis,	
205509	Supply Chain for New Venture	2(2-0-4)	None	Introduction to logistics and supply chain for new venture, demand management, resource planning, material flow, procurement and inventory, transportation systems, warehouses, distribution systems, reverse logistics, logistics cost, and outsourcing.	
205510	Venture Capital and Private Equity Investing	2(2-0-4)	None	Principles and methods of fund raising and business value, business decision making regarding risk and return of investment, venture capital and private equity investing, social impact investors, deal structure evaluation and negotiation, value creation and exit strategies.	
205511	Legal Aspects of Entrepreneurship	2(2-0-4)	None	Introduction to laws, person and property, juristic acts, contract, obligation, wrongful acts, sale, hire of property, hire purchase, surety ship, pledge, mortgage, bills and cheques, partnership, limited company, shares, stock exchange, employment laws, tax laws, electronic commerce and unfair contract terms.	