

PROPOSAL FOR REVISION OF THE MATHEMATICS GRADUATE PROGRAM AT WIU

DEPARTMENT OF MATHEMATICS

ABSTRACT. We wish to revise the structure of our MS program effective Fall of 2006, and call it “Professional Master’s degree in Mathematics with a focus in [Focus Area]” (where [Focus Area] could be a variety of possibilities from a number of areas), which will prepare the students for jobs in our region and nationwide. The program will consist of 8 core courses and 4 focus area courses which will allow for focus in various areas of applied and pure mathematics as well as other areas of study outside the Department of Mathematics, as approved by the Graduate Committee. For example, the focus area courses may be in statistics, numerical analysis, mathematics education, PhD track, biology, business, chemistry, computer science, economics, or physics.

The program will consist of two steps. The first step will consist of six courses (C1-C6, with C1-C4 as core courses and C5-C6 as focus area courses or credit for professional experience), leading to a Certificate Degree; and the second step will consist also of six courses (M1-M6 with M1-M4 as core courses and M5-M6 as focus area courses, a thesis, a project or an internship), leading to a Master of Science Degree. (For the MS degree with focus in teaching mathematics option, two M-core courses in math education: M* and M** will substitute for two of M1-M4.)

The revised program will provide students with a solid, graduate level training in the central and fundamental methods of continuous and discrete mathematics. Both the theoretical framework and the applications of these methods will be covered in the core courses (C1-C4 and M1-M4.) The C1-C4 will have a significant lean toward applications but theory will be present; while the M1-M4 courses will have a significant lean toward theory/mathematical foundation but applications will not be abandoned. The C5-C6 and M5-M6 courses will share a common thread, with C5 and C6 offered as Math 599 (special topics course, 3 s.h., which may be repeated for credit) and with M5 and M6 offered as Math 699 (a new special topics course, 3 s.h., which may be repeated for credit.)

The course numbers for C1-C4, M1-M4, M* and M** are shown in Table 1; and their titles and catalog descriptions listed in Section 1.

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1. CATALOG DESCRIPTIONS OF CORE COURSES IN THE REVISED PROGRAM

- C1/Math 551 (Methods of Classical Analysis): 3 s.h. Introduction to complex and multivariable analysis with a significant lean toward applications. Topics include sequences and series, conformal mappings, complex integration, geometry and topology of R^n , Newton's method and Taylor polynomials, extreme values of functions on R^n , manifolds and their tangent spaces.
- C2/Math 552 (Scientific Computing with MATLAB): 3 s.h. Design, analysis, and MATLAB implementation of algorithms for solving problems of continuous mathematics involving linear and nonlinear systems of equations, interpolation and approximation, numerical differentiation and integration, and ordinary differential equations with a significant lean toward applications.
- C3/Stat 553 (Applied Statistical Methods): 3 s.h. Introduction to probability and statistics with a significant lean toward applications. Topics include probability, important probability distributions, Central Limit Theorem, sampling distributions (t, F, Chi-Square), hypothesis testing, nonparametric statistics, ANOVA, linear regression.
- C4/Math 554 (Methods of Symmetry in Algebra): 3 s.h. A study of symmetry in algebra, geometry, and topology with a significant lean toward applications. Topics of study include group of Euclidean transformations,

symmetries of planar sets, topological classification of compact surfaces, crystallographic patterns and classification of their symmetry groups.

- M1/Math 651 (Elements of Modern Analysis): 3 s.h. A study of elements of modern analysis with a lean toward developing the theory. Topics include topology in normed linear spaces; inner product spaces, Hilbert space, Fourier series; equicontinuity and Arzela-Ascoli theorem, Banach contraction principle, Picards theorems, Peano's theorem; Gateaux differential and the Euler-Lagrange equation; compact operators and existence of solutions of Fredholm integral equations.
- M2/Math 652 (Computational Differential Equations): 3 s.h. A study of elements of computational mathematics of differential equations with a lean toward developing the theory. Topics include adaptive one-step and multi-step methods for ordinary differential equations, finite difference and finite element methods for partial differential equations, the method of lines for evolutionary problems, and direct and iterative methods for sparse linear systems.
- M3/Stat 653 (Elements of Statistical Inference): 3 s.h. A study of elements of computational mathematics of differential equations with a lean toward developing the theory. Topics include adaptive one-step and multi-step methods for ordinary differential equations, finite difference and finite element methods for partial differential equations, the method of lines for evolutionary problems, and direct and iterative methods for sparse linear systems.
- M4/Math 654 (Computability, Complexity, and Logic): 3 s.h. A study of elements of modern logic and computability with a lean toward developing the theory. Topics include the mathematics of computability and incomputability, introduction to computational complexity, and additional applications of logic.
- M*/Math 655/Math 503 (Methods of Teaching Secondary School Mathematics): 3 s.h. A study of current trends and problems in the teaching of secondary school mathematics.
- M**/Math 656 (Advanced Perspective of Secondary School Mathematics) 3 s.h. An advanced study of the mathematics of secondary school curriculum for the purpose of developing deeper connections and representations for all students. Focus is on rigorous conceptual content knowledge, methods of inquiry, and investigative problem-solving. Topics include Algebra, Geometry, and Statistics.

C1: Math 551	C2: Math 552	C3: Stat 553	C4: Math 554
M1: Math 651	M2: Math 652	M3: Stat 653	M4: Math 654
M*: Math 655/Math 503	M**: Math 656		

TABLE 1. Core courses in the revised graduate program

2. PROPOSED GRADUATE PROGRAM REVISIONS

In this section, we present the philosophy behind revising our current graduate program as well as the proposed courses and options in the revised program.

2.1. Reasons for Revision. Our present graduate program is basically a traditional program, which is supposed to give a student a solid foundation in some of the major areas of mathematics. While this is an appropriate setting for a student who will continue his/her studies at a doctorate granting institution, it does not provide the experience of applying mathematics that a student with a professional Master's degree needs.

2.2. Proposed Revisions: A Certificate and a Masters. Our students come from varied backgrounds with different degrees of academic preparation and diverse career goals. We are planning to implement a program that will be accessible to them and meaningful regardless of their career goals. There will be two possible steps in our graduate program: the earning of a Certificate and the earning of a Master's degree. To some extent, this will be modelled similar to the traditional undergraduate degree where students first learn a significant amount of applications in the calculus sequence and then learn the supporting theory in advanced courses.

There will be core courses for the Certificate and for the Master's. The Certificate core courses will be focused on practical applications of mathematics, without emphasis on deep understanding of the theory behind them, putting to use the knowledge that a student had learnt in upper division courses and exploring new tools. This will ensure that the recipients of a Certificate will have a working knowledge of mathematics that can be applied to real-life problems. As prerequisites for the Certificate core courses, a student will be required to hold a bachelor degree in mathematics, statistics or a related area and have a strong background in undergraduate mathematics at the senior level.

The Master's core courses will go deeper in theoretical underpinnings of the subjects covered in the Certificate portion of the program. At both steps, the focus area courses (or experience, thesis, project, internship) will offer a student possibilities to gain experience in diverse areas of mathematics and cognate areas. Therefore, a student might have the option of taking courses in other departments. Because of the solid core and a broad range of non-core courses, it is expected that the program will be able to serve the needs of a diverse population. In particular, the employment possibilities for our students should improve, while still maintaining the option for our graduating students to proceed into a PhD program.

2.3. Actions Taken. In pursuit of defining a revision of the graduate program, the Graduate Committee and the Department Chair met with the Dean on April 29, 2003 to get her reaction to the proposals for new programs. Her input was brought for discussion at a graduate faculty meeting on May 6, 2003. Following the Dean's concerns about competing with existing programs, and possible enrolments, a motion was passed that "the Graduate Committee develop a Master's Degree program with multiple tracks and having a core that is accessible to students from many majors".

In Summer 2004, the Department Chair discussed the planned revisions in the graduate program with Dean Levi and Provost Rallo and then reported on those discussions to the Mathematics Graduate Committee Chair and later to the Graduate

Committee on August 26, 2004. The Graduate Committee discussed the structure and the contents of the courses during their regular weekly meetings in the Fall and Spring semesters of the 2004-2005 academic year and asked the various groups within the Department of Mathematics to submit proposed outlines for the core courses as well as samples for possible focus area courses. Then the Graduate Committee called for Department meetings to discuss the structure of the program as well as the proposed outlines for the core courses, which had been approved by the Graduate Committee.

In Subsection 2.4, we present the main points in the structure of the revised graduate program (approved by the Department on February 15, 2005) with minor changes in the prerequisites for the M-core courses, based on the later presentations of those courses (on April 22, 24 and 29). Then in Section 4, we present the proposed outlines for the core courses, which were approved by the Department on March 22, 2005 (C1 and M1), on March 24 (C2, M2, C3 and M3) and on March 29 (C4 and M4), subject to revisions later when the program is considered as a whole.

2.4. Revised Program Options. The graduate program will be divided into two parts. The first part will consist of 6 courses, four of which will be core and the remaining two will be in a focus area, either in our graduate program or in a different department. Upon the completion of the first part, a student will be awarded the Certificate in Mathematics with focus in [Focus Area], where [Focus Area] can be statistics, numerical analysis, teaching mathematics, biology, business, chemistry, computer science, economics, physics, or any related area of study approved by the graduate committee. The goal of the six courses leading to the Certificate is to give a student mathematical tools that have real-life applications, without going in depth into the theory of why those tools work.

Upon the completion of the first part, a student will be able to continue with the second part that will lead to Professional M.S. in Mathematics with a focus in [Focus Area], where [Focus Area] can be statistics, applied mathematics, teaching mathematics, PhD preparation, biology, business, chemistry, computer science, economics, physics, or any related area of study approved by the graduate committee. There will be four core courses in this part and the additional two will be in a focus area, either in our graduate program or in a different department.

The specific courses for the revised program, with their names and numbers, are given in the table below.

Analytical methods of continuous mathematics will be covered in C1 and M1 (with a suitable fragment of the theoretical framework of continuous mathematics in M1.) Numerical methods will be covered in C2 and M2; statistical and probabilistic methods will be covered in C3 and M3; and discrete methods (in a broad sense) will be discussed in C4 and M4.

C5 and C6 will be focus area courses which may be in various areas of applied and pure mathematics as well as other areas of study outside the Department of Mathematics (see Abstract above), as approved by the Graduate Committee. Furthermore, possible experience can translate into earned credit for C5 or/and C6. Within the Department of Mathematics, C5 and C6 will be offered as Math 599 (topics course, 3 s.h., which may be repeated for credit.)

M5 and M6 will be focus area courses which may be in various areas of applied and pure mathematics as well as other areas of study outside the Department of Mathematics (see Abstract above), as approved by the Graduate Committee. M5

Certificate courses	Post-Certificate courses
C1 or Math 551 : Methods of Classical Analysis	M1 or Math 651 : Elements of Modern Analysis
C2 or Math 552 : Scientific Computing with MATLAB	M2 or Math 652 : Computational Differential Equations
C3 or Stat 553 : Applied Statistical Methods	M3 or Stat 653 : Elements of Statistical Inference
C4 or Math 554 : Methods of Symmetry in Algebra	M4 or Math 654 : Computability, Complexity, and Logic
C5 or Math 599 : Focus area course, or professional experience	M5 or Math 699 : Focus area course, or thesis, or project, or internship
C6 or Math 599 : Focus area course, or professional experience	M6 or Math 699 : Focus area course, or thesis, or project, or internship
	<u>For Teaching Math. track ONLY</u> replacing two of M1-M4 M* or Math 655 : Math 503 M** or Math 656 : Advanced Perspective of Secondary School Math.

TABLE 2. Proposed courses for the revised graduate program

and M6 can also be a thesis, a project, or an internship. Within the Department of Mathematics, M5 and M6 will be offered as Math 699 (a new topics course, 3 s.h., which may be repeated for credit.)

Many of the courses in the focus areas (C5, C6, M5, M6) within the Mathematics Department (four courses per focus area) will be offered as independent studies, while some of those courses will be scheduled like normal courses if there is enough demand. Hence the course outlines for most of these courses will remain flexible; and the detailed outlines will be decided by the faculty depending on the interest of the students taking the courses. In the event that C5, C6, M5, M6 are small classes needed by a small group of students, the department will make specific arrangements to be supportive of the faculty teaching those courses.

In the revised program, C1 and Math 435 (or equivalent) will be prerequisites for M1; (C1 or Math 435) and (C2 or Math 481) will be prerequisites for M2; and C3 and Stat 471 (or equivalent) will be prerequisites for M3. A student who has not had the prerequisite courses in their undergraduate program would have to take those courses as deficiency courses. A student seeking an MS degree may count up to two of the courses 424G, 435G, 471G, and 481G as C5 and/or C6 with approval of the Graduate Committee. Also in order to maintain the undergraduate program,

the Department will continue to offer the current MS core courses (MATH 424, 435, 481, and STAT 471) which are also a part of the undergraduate program even if these classes will have a small number of students.

Candidates who hold secondary school teaching certification may, with permission of the Graduate Committee, substitute course work in geometry for C4 if they are seeking the Certificate degree, and for any of the courses C4-C6 if they are seeking the MS degree.

Finally, an MS student with focus in teaching mathematics will substitute M* (Math 503) and M** (Advanced Perspective of Secondary School Mathematics) for two of M1-M4.

2.5. Actions Planned.

- Assess the need for the new program in the Quad Cities.
- Build on the existing program's strengths to develop new programs that will train students for professions with positive employment outlook.
- Pursue the development of new programs and establish ties with regional industries through cooperation and internships.
- Expand the recruitment efforts through the GRE Search Service.
- Work closely together with the undergraduate program to recruit our better undergraduate students for the graduate program.

3. DEGREE REQUIREMENTS

Before we state the requirements for both the Certificate Degree and the M.S. Degree, we note in passing that the Department's Graduate Committee has approved (Spring 2004) the following change in admission requirements and application for assistantship: The general part of the GRE will be recommended for admission and required for receiving an assistantship.

3.1. Certificate Degree.

3.1.1. Current Program. No certificate degree is currently offered.

3.1.2. **Proposed Program**. To earn a Certificate Degree, a student must successfully complete the following four core courses,

- C1/Math 551 (Methods of Classical Analysis): 3 s.h.
- C2/Math 552 (Scientific Computing with MATLAB): 3 s.h.
- C3/Stat 553 (Applied Statistical Methods): 3 s.h.
- C4/Math 554 (Methods of Symmetry in Algebra): 3 s.h.

and two focus area courses

- C5/Math 599 (Focus area course, or professional experience): 3 s.h.
- C6/Math 599 (Focus area course, or professional experience): 3 s.h.

to be approved by the Graduate Committee for each student.

3.2. Master's of Science Degree.

3.2.1. Current Program. The M.S. degree in mathematics may be earned under one of three plans described below. In each plan the student will have successfully completed the following four core courses:

- MATH 424G (Advanced Linear Algebra): 3 s.h.
- MATH 435G (Introduction to Real Variables I): 3 s.h.
- MATH 481G (Numerical Analysis I): 3 s.h.
- STAT 471G (Introduction to Mathematical Statistics I): 3 s.h.

Oral Examination Plan. (30 semester hours) Under this plan, the student must earn 30 graduate semester hours in approved course work, including the core courses, and pass an oral examination. Of the 30 semester hours, at least 15 must be in 500-level courses. The oral examination is over a portion of the student's course work. Students may choose this portion with the approval of their advisory committee.

Thesis Plan. (33 semester hours) Including the core courses, the student must earn 30 semester hours in approved course work and three semester hours of MATH 600, Thesis. Of the 30 semester hours in course work, at least 15 must be in 500-level courses. The thesis may be either expository, historical, critical, or original and must be approved by the student's advisory committee. The student will present his/her thesis to the Mathematics Department faculty in a colloquium.

Course Work Plan. (36 semester hours) The student must earn 36 semester hours in approved course work including the core courses. Of these, at least 18 semester hours must be in 500-level courses.

A student who has completed a course equivalent to any of the core courses as a part of the undergraduate program would, of course, be exempted from that course requirement. Also, candidates who hold secondary school teaching certification may, with permission of the Graduate Committee, substitute course work in geometry for any one of the courses mentioned above except MATH 435G, Introduction to Real Variables I.

Students may, with approval of the Graduate Committee, include up to six semester hours in a cognate area such as biology, chemistry, physics, economics, computer science, etc. If education is chosen as a cognate area, no more than nine semester hours of the program may be completed in mathematics methods and education courses.

A student may receive credit for the maximum number of transfer and extension hours allowed by the School of Graduate Studies.

Each graduate assistant is required to complete at least nine semester hours in Mathematics in each semester of the first year. Any exception to this policy must be approved in writing by the Graduate Committee.

3.2.2. Proposed Program. To earn an MS degree, the student will have successfully completed the following courses:

- C1/Math 551 (Methods of Classical Analysis): 3 s.h.
- C2/Math 552 (Scientific Computing with MATLAB): 3 s.h.
- C3/Stat 553 (Applied Statistical Methods): 3 s.h.
- C4/Math 554 (Methods of Symmetry in Algebra): 3 s.h.
- C5/Math 599 (Focus area course, or professional experience): 3 s.h.
- C6/Math 599 (Focus area course, or professional experience): 3 s.h.
- M1/Math 651 (Elements of Modern Analysis): 3 s.h.

- M2/Math 652 (Computational Differential Equations): 3 s.h.
- M3/Stat 653 (Elements of Statistical Inference): 3 s.h.
- M4/Math 654 (Computability, Complexity, and Logic): 3 s.h.
- M5/Math 699 (Focus area course, or thesis, or project, or internship): 3 s.h.
- M6/Math 699 (Focus area course, or thesis, or project, or internship): 3 s.h.

A student with focus in teaching mathematics will substitute

- M*/Math 655 (Math 503) and
- M**/Math 656

for two of M1-M4.

A student may receive credit for the maximum number of transfer and extension hours allowed by the School of Graduate Studies.

A student who has had any of C5, C6, M5 or M6 in his/her undergraduate degree may apply for credit in at most two of those courses to apply towards his/her Certificate or MS degree.

A student who successfully writes and defends a thesis may earn credit for M5 and M6.

Each graduate assistant is required to complete at least nine semester hours in mathematics in each semester of the first year. Any exception to this policy (particularly for cognate courses) must be approved in writing by the Graduate Committee.

4. PROPOSED COURSES DESCRIPTIONS

In this section, we present the proposed outlines for the core courses, which were approved by the Department on March 22, 2005 (C1 and M1), on March 24 (C2, M2, C3 and M3) and on March 29 (C4 and M4), subject to revisions later when the program is considered as a whole. We also include the proposed courses M* and M** that a student with focus in teaching mathematics will substitute for two of M1-M4.

C1/Math 551 (Methods of Classical Analysis): 3 s.h.

Prerequisites: Math 231 and Math 311 (or equivalent)

- Complex Analysis (50%)
 - Complex numbers and their polar representation
 - Sequences and Series of complex numbers
 - Analytic functions and Conformal Mappings
 - Review of Line Integrals, Independence of Path, and Green's Theorem
 - Complex Line Integral and the Fundamental Theorem of Calculus
 - Cauchy's Theorem and Cauchy Integral Formula
 - Power Series: Criteria for uniform convergence and Weierstrass M-Test, Properties assured by uniform convergence
 - Laurent Series and Isolated Singularities and The Residue Calculus
 - Periodic Functions and Fourier Series
 - Applications to Fluid Dynamics, Steady State Heat Flow, and Electrostatics
- Multivariable Analysis (50%)

- Geometry of \mathbb{R}^n : the dot product, length, angle, and Schwarz's Inequality.
- Convergence and Limits in \mathbb{R}^n : open, closed, and bounded sets, convergence of sequences, subsequences, closure of a set, limit of functions from \mathbb{R}^n to \mathbb{R}^m , continuity of functions from \mathbb{R}^n to \mathbb{R}^m , existence of minima and maxima of continuous real-valued functions on closed and bounded subsets of \mathbb{R}^n .
- Differential Calculus in \mathbb{R}^n : directional derivatives, the Jacobian matrix and the derivative of a function from \mathbb{R}^n to \mathbb{R}^m , the Chain Rule, the Mean Value Theorem, criterion for differentiability, and higher order partial derivatives.
- Newton's method in \mathbb{R}^n : Lipschitz conditions and Kantorovitch's theorem.
- The inverse and implicit function theorems : statement, examples, and applications.
- Manifolds: defining manifolds by equations and parametrizations, tangent space to a manifold
- Taylor Polynomials in \mathbb{R}^n
- Finding Maxima and Minima of Functions on \mathbb{R}^n : positive definite and negative definite quadratic forms on \mathbb{R}^n , the second derivative criterion, quadratic forms and extrema, behavior of functions near saddle points, degenerate critical points.
- Constrained Critical Points and Lagrange Multipliers.
- Applications to Mechanics, Economics, and Geometry.
- References:
 - Robert Gameline, Complex Analysis, Springer-Verlag 2000
 - John Hubbard and Barbara Burke Hubbard, Vector Calculus, Linear Algebra, and Differential Forms, A Unified Approach, Prentice Hall 1999

C2/Math 552 (Scientific Computing with MATLAB): 3 s.h.

Prerequisites: Linear Algebra (Math 311) and Ordinary Differential Equations (Math 333)

- (1) Solutions of Linear Systems $AX=B$
 - Gaussian Elimination
 - LU factorization
- (2) Solution of Nonlinear Equations $f(x)=0$
 - Newton's Method
 - Secant Method
 - Error Analysis
 - Nonlinear Systems of Equations
- (3) Interpolation, Approximation and Optimization
 - Polynomial Interpolation (Lagrange, Hermite Polynomials)
 - Interpolation using Spline Functions
 - Least Squares Approximation
- (4) Numerical Differentiation and Integration
 - Trapezoidal and Simpson Rules
 - Error Formulas

- Gaussian Numerical Integration
- Numerical Differentiation
- (5) Solution of Ordinary Differential Equations
 - Euler's Method
 - Convergence Analysis of Euler's Method
 - Runge-Kutta Methods
- (6) References:
 - Numerical Computing with MATLAB, Cleve Moler, SIAM
 - Scientific Computing: An Introductory Survey, Michael Heath, McGraw-Hill

C3/Stat 553 (Applied Statistical Methods): 3 s.h.

The goal of this course is to prepare our students who enrolled in the certificate program for a competitive environment that requires certain statistical knowledge and software experience. Therefore, our main goal should be the introduction of statistical methods that are commonly used in the industry as well as in the other graduate level courses.

Prerequisites

We would like to offer this course to somebody that has already a college degree and taken at least 200 level college mathematics course(s). Therefore, Math 231 and Stat 276 equivalent as prerequisite should be considered enough for this course.

Course Outline

- Review of Probability and Counting Principles
- Random Variables and Probability Distribution Functions
- Survey of Important Probability Distributions(Binomial, Normal)
- Sampling Distributions : T, F, Chi-Square
- Estimation Problems in Statistics
- Confidence Interval Estimation for One and Two Sample
- Hypothesis Testing: One and Two Sample Problems
- Categorical Data Analysis: RxC Contingency Tables
- Linear Regression
- Nonparametric Statistics

Optional Topics (Not limited to the following topics)

- Bootstrap Estimation
- ANOVA(Analysis of Variance Technique)
- MANOVA(Multiple Analysis of Variance Technique)

Software

SAS, SPSS, S-plus, MINITAB, MATLAB, or JMP will be available in our department. One or two will be used in this course depending on Instructors choice. We would like to teach our students one or two statistical software that would help for them later in their professional life

C4/Math 554 (Methods of Symmetry in Algebra): 3 s.h.

Proposed course outline

- (1) Congruence via Euclidean transformations and equivalence relations.
- (2) The group of Euclidean transformations.
- (3) Group actions and orbit spaces.
- (4) Finite subgroups of the group of Euclidean transformations of the plane $\mathcal{I}(E^2)$.

- (5) Symmetry groups of subsets of Euclidean plane (space).
- (6) Classification of symmetries of patterns on a disc.
- (7) Crystallographic patterns and the action of their groups of symmetries.
- (8) Topological classification of surfaces
- (9) Graphs on surfaces, Euler characteristic, and Gauss-Bonnet Theorem.
- (10) Classification of the symmetry groups of crystallographic patterns.

Course objectives

The course will bring together some ideas of geometry, algebra and topology. The notion of congruence leads to isometries of the Euclidean plane and to group actions. Quotient spaces corresponding to actions of symmetry groups are the natural “stamps” of patterns, carrying with them minimal groups of symmetries (like in the case of a painter’s roller). Therefore, a classification of these “stamps” leads to a classification of groups of symmetries, in particular to the classification of the symmetry groups of crystallographic patterns. The interplay between geometry, algebra and topology is natural, and brings about these classification results in a geometric way. The intent of the course is to give a student a feel for modern mathematics in a down to earth fashion, and to give those students who are teachers some knowledge that will be useful in the classroom.

Besides the mathematical part the course will include projects that will explore the occurrence of symmetries in nature, and the reasons for that (for example the reasons for the occurrence of hexagonal patterns).

Possible textbook

D.L. Johnson, Symmetries, Springer-Verlag 2001

Abundance of web materials, for example <http://ccins.camosun.bc.ca/~jbritton/jbsymteslk.htm>

M1/Math 651 (Elements of Modern Analysis): 3 s.h.

Prerequisites: Math 435 (or equivalent)

- Logic and Set-theory;
- Riemann Integral: Differentiation under the integral sign, Improper Riemann Integrals, Measure Zero and Lebesgue’s theorem;
- Uniform and L^1 Norms on $C[a,b]$, Topology in Normed Linear Spaces (including Completeness and Sequential Compactness);
- Inner Product Spaces, Cauchy-Schwarz Inequality, Orthonormal Sets, the space $C[-\pi, \pi]$ under L^2 norm, and definition of trigonometric polynomials and Fourier Series
- Projection maps and Projection Theorem, Bessel’s Inequality, Hilbert Space, completeness of the space ℓ^2 , Parseval’s Theorem, Compactness in finite-dimensional normed linear spaces
- Sequences and Series of Functions: uniform convergence and continuity, uniform convergence and integration, term-by-term differentiation of Series, Equicontinuity and Arzela-Ascoli Theorem;
- Compactness, completeness and Connectedness in Metric Spaces;
- Completion of a Metric Space, Tietz’s Extension Theorem and The space $L^p[a, b]$ as the completion of $C[a, b]$ in the L^p norm, and Monotone Convergence Theorem in $L^p[a, b]$.
- **Applications**
 - (1) Ordinary Differential Equations

Fixed Points and the Banach Contraction Principle, Global and Local Picard Theorems, Existence of Solutions of Ordinary Differential Equations, Peano's Theorem.

- (2) Calculus of variation: Gateaux Differential and The Euler-Lagrange Equation
- (3) Integral Equations: Compact Operators, Schauder's Theorem, The Spectrum of Compact Operators, Existence of solutions of Fredholm Integral Equations.

- References:

- Davidson, K. R. and Donsig, A. P., Real Analysis with Real Applications, Prentice Hall 2002.
- Ruckle, W.H., Modern Analysis, PWS-Kent Publishing Company 1991

M2/Math 652 (Computational Differential Equations): 3 s.h.

Prerequisites: (C1 or Math 435) and (C2 or Math 481)

- (1) Ordinary Differential Equations
 - One-step and multi-step methods for ODEs with error control.
 - Accuracy, stability, and convergence properties.
 - Modifications of Newton's method for implicit solvers on stiff problems.
- (2) The Poisson Equation
 - Finite Difference and Finite Element Methods
 - Direct and Iterative methods for sparse linear systems
 - Multigrid techniques and Fast Poisson Solvers.
- (3) PDEs of Evolution
 - Diffusion equation
 - Hyperbolic equations
 - Method of Lines
- (4) References: A First Course in the Numerical Analysis of Differential Equations, A. Iserles, Cambridge Texts in Applied Mathematics

M3/Stat 653 (Elements of Statistical Inference): 3 s.h.

The goal of this course is to teach our students fundamental theorems and applications that will be need in their post-graduate work. The topics that will be covered are also applicable in the industry that requires certain knowledge of statistical theory.

Prerequisites

The level of this course requires some Statistics background at Stat-471 level. Therefore, we would like put Stat-471 and C3 as prerequisites for this course.

Course Outline

- Probability Theory
- Some Probability Distributions: Discrete/Continuous Cases
- Mathematical Expectation: Moments, Variance
- Limit Theorems: Chebyshev's Theorem, Convergence
- Point Estimation Theory
- Properties of the Estimators: Unbiasness, Efficiency, Consistency, The Rao-Cramer Lower Bound
- Confidence Interval Estimation Theory

- Hypothesis Testing Theory: Type-I and Type-II Error, The Neyman-Pearson Lemma, Likelihood Ratio Tests
- Bayesian Point Approach to Statistical Inference
- Nonparametric Estimation Theory
- Bootstrap Methods

Optional Topics (Not limited to the following topics)

- Categorical Data Analysis
- Regression and Correlation
- Design and Analysis of Experiments

Software

SAS, SPSS, S-plus, MINITAB, MATLAB, or JMP will be available in our department. One of them will be used in this course depending on Instructors choice. We would like to teach our students one or two software that would help for them later in their professional life

M4/Math 654 (Computability, Complexity, and Logic): 3 s.h.

- Catalog Description: Introduction to the mathematics of computability and noncomputability, introduction to computational complexity, and additional applications of logic.
- Explanation:
 - (1) In the "introduction to the mathematics of computability and noncomputability", the principal goal is to define a mathematical framework(s) that precisely characterizes "computability" [e.g., Turing machines], and develop the theory sufficiently so as to be able to demonstrate that such problems as the "halting problem" cannot be solved computably.

Typical subtopics: Models of computability, equivalence of characterizations of computability, recursive and recursively enumerable sets, the halting problem and other 'unsolvable' problems.
 - (2) In the introduction to computational complexity, the principal goal is to discuss and explore various measures of computational complexity [e.g., non-deterministic polynomial time], and develop the theory sufficiently so as to thoroughly show the meaning of the 'P=NP?' problem.

Typical subtopics: Measures of complexity [linear/polynomial/exponential in time/space], NP-complete problems, comparisons of complexity measure. Note: Many standard examples are questions in the field of graph theory. [For example: the problem of deciding whether a graph has a Hamilton circuit is an NP-complete problem.]

Topics (1) and (2) should comprise approximately 50% of the course. Possible additional major topics of the course may include:

A: Randomness from the computability/information theory perspective. That is, exploration of Kolmogorov and related concepts defining a finite sequence to be 'random' when it has no compressed description.

B: Varieties of logic, with applications. For example, 'non-monotonic logics' as a model of how to revise beliefs in the face of contradictory evidence.

C: Additional study of computability/noncomputability and/or computational complexity, beyond the basics outlined above. [Note however that

the proposed catalog description speaks of "additional applications of logic" in addition to these areas.] .

M*/Math 655 (Math 503)

M/Math 656 (Advanced Perspective of Secondary School Mathematics)**

- (1) Title: In-Depth Analysis of Secondary Mathematics
- (2) Key components: Advanced perspective of secondary topics like Algebra, Geometry and Statistics.
- (3) Textbook: Mathematics for High School Teachers-An Advanced Perspective By Usiskin, Peressini, Marchisotto, Stanley Note: Dr.s Stanley (Berkeley) and Peressini (UIUC) conducted a weeklong workshop using this text on our campus in the summer of 2003 and this course would be built upon similar principles.
- (4) Outline:
 - Functions, Equations and Solving
 - Number sets, systems, and structures
 - Integers and Polynomials
 - Congruence, similarity, and distance
 - Area and Volume
 - Axiomatics and Euclidean Geometry

This course would parallel are current Math 304 (Pedagogical Content Knowledge) course for undergraduate Option B majors.
- (5) Prerequisites: Admission in the Graduate program
- (6) Software required for the class:
 - Graphing calculators would be required
 - Geometer's Sketchpad

In support of our proposals for revisions, we include in Section 6 (Appendix B below) the most recent program review which was completed and approved by the Department's Graduate Committee. In particular, Subsections 6.5, 6.6 and 6.7 are of great relevance.

5. APPENDIX A [POTENTIAL FOCUS AREA COURSES IN THE DEPARTMENT]

5.1. C5-C6/Math 599.

5.1.1. *Teaching Mathematics.*

Technology and the Secondary Mathematics Curriculum: 3 s.h.

- Course Outline:
 - I. Overview of the Technology and Instructional Issues
 - A. Introduction to the Use of Calculators (including graphics calculators and computer algebra system (CAS) calculators)
 - B. Introduction to the Use of Computers
 1. Basic principles, menus, and file management.
 2. Basics of electronic spreadsheets.
 3. Multimedia software.
 4. Software evaluation
 - C. Introduction to Internet Use
 1. Navigation, search, and downloading basics.
 2. Creating a World Wide Web homepage.

3. Internet site evaluation.
- D. Introduction to Planning for Instruction with Technology Issues
 1. Publications on the use of technology in the classroom.
 2. Research on the use of technology in the classroom.
 3. Classroom structure (including the one-computer classroom, multiple-computer classroom, computer lab use.)
 4. Presentation software.
- II. A Closer Look at Technology and Instructional Issues
 - A. Investigating Functions and Relations Using Technology
 1. Using calculators.
 2. Using computers. Maple, Function Explorer, WinPlot, Excel.
 3. Using the Internet.
 4. Planning for Instruction.
 - B. Investigating and Discovering Geometry Concepts Using Technology
 1. Using calculators. TI-92
 2. Using computers. Geometers' Sketchpad
 3. Using the Internet.
 4. Planning for Instruction.
 - D. Probability and Statistics (Data Analysis) Using Technology
 1. Using calculators.
 2. Using computers. Excel, Fathom.
 3. Using the Internet.
 4. Planning for Instruction.

Note that I - introduction makes up about 25% of the course. II makes up 75% of the course.

- Prerequisites: Permission of the instructor.
- Faculty members who can teach this course: Dr. Olsen and Dr. Mann
- Software required for this class: Geometer's Sketchpad, MS Office (Excel, Word, etc.), Maple, Fathom.

Teaching Trigonometry and AP Calculus: 3 s.h.

- Course Outline:
 - Analysis of various approaches to trigonometric functions (right triangle trigonometry, trigonometric functions, and circular functions).
 - Representations to illuminate trigonometry concepts (physical and electronic).
 - The AP Calculus syllabus (from the College Board) and exam study guides. This will make up a major portion of the course.
 - The use of a Computer Algebra System and graphics calculator in the teaching of calculus.
 - Representations to illuminate calculus concepts (physical and electronic).
 - Applications of trigonometry and calculus.
 - Pedagogical issues related to the teaching of trigonometry and calculus.
- Prerequisites: Minimum prerequisite is one semester of calculus. Two or more semesters of calculus preferred.
- Faculty members who can teach this course: Olsen, Mann, and Lawton have expressed interested, but many other faculty could teach the course.

- Software required for this class: Computer Algebra System on a calculator as per the required/allowed by the College Board for the AP Calculus Exam.

5.1.2. *Applied Mathematics/Numerical Analysis.*

Linear Methods of Applied Mathematics: 3 s.h.

- Key components: Analysis from linear algebra perspective (Fourier series)/elements of functional analysis/ODE's/PDE's
- Course Outline: Fourier series/transform, linear algebra, eigenvalues/eigenvectors/eigenfunctions, boundary value problems for ODE's/PDE's, linear algebra, applications
- Prerequisites: Calculus, Math 311 (Linear Algebra), Math 333 (Ordinary Differential Equations)
- Faculty members who can teach this course: Dr. Andreev - anybody else who can teach 430 and/or 424
- Software required for this class: Maple.

5.1.3. *Statistics.*

Principles and Procedures of Statistics: 3 s.h. Topics among which to choose:

- I. Essentials of Probability
- II. Random Variables and Probability Distributions
- III. Normal Distributions
- IV. Estimation of Parameters for a Population
- V. Testing Parameters for a Population
- VI. Testing Parameters for Two Populations
- VII. Testing Parameters for more than Two Populations
- VIII. Analysis of Variance I: The One-Way Classification
- IX. Multiple Comparisons
- X. Principles of Experimental Design
- XI. Analysis of Variance II: Multiway Classifications
- XII. Linear Regression of Single Explanatory Variable
- XIII. Multiple Regression
- XIV. Correlational Analysis
- XV. Analysis of Covariance
- XVI. Chi-Square Analysis
- XVII. Contingency Tables
- XVIII. Nonparametric Statistics
- XIX. Elementary Multivariate Statistical Analysis
- XX. Elements of Statistical Process Control
- XXI. Elementary Time Series Analysis

The educational approach of this course is to use statistical software to introduce many types of experimental situations to which statistical solutions are obtained by use of software. The problem's solution, once determined by the software routine, is then the basis of learning the background constructs of the problem, the statistical assumptions for such a solution, and the evaluation and interpretation of the solution. Therefore, a successful student will not only learn how to use statistical software, but the example problems and their statistical solutions will provide the emphasis for learning statistical procedures and their interpretations.

The particular statistical software is not so much of importance but the obvious choices of SPSS, SAS, or S-Plus are readily available examples from which to choose.

A textbook probably is not as important as is the need to find a good manual that describes the various statistical routines in the computer software. An example of such a manual would be the SPSS 10.0 Guide to Data Analysis by Marija J. Norusis (Prentice Hall; ISBN 0-13-0029204-4) or its equivalent for other software.

5.1.4. *Open.*

Elements of Modern Geometry/Topology/Graph theory: 3 s.h.

- Key components: Topology of Surfaces/Fundamental groups/Differential Forms/Graphs (on the surfaces)
- Course Outline:
 - Surfaces (orientation, genus)
 - Homotopy
 - Fundamental group
 - Fixed point theorem
 - Homology/Cohomology
 - Calculus of differential forms
 - Stokes theorem
 - Notion of sphere groups ($\pi_n(S^m)$)
 - Graphs
 - Planar graphs
 - Graphs on the surfaces
 - Covering
- Prerequisites: Calculus
- Faculty members who can teach this course: Dr. Andreev.
- Software required for this class: None other than some applets developed by Dr. Andreev can be occasionally used.

Number Theory with Elements of Geometry: 3 s.h.

- Basic Number Theory/Elements of Algebraic Geometry/Elliptic Curves/Applications to Cryptography/Computations
- Course Outline:
 - Number theory (mod p , factoring over \mathbb{Z} , prime number algorithms)
 - Fields/Rings
 - Varieties and their Ideals
 - Elements of Projective geometry
 - Bezout theorem
 - Elliptic curves
 - Genus (elementary algebraic topology)
 - Multiplication on elliptic curves
 - Groups (with more attention to abelian groups)
 - RSA encryption and cryptography
 - Computation: algebraic numbers, algorithms, software packages
- Prerequisites: Math 311.
- Faculty members who can teach this course: Dr. Andreev.
- Software required for this class: Free software downloadable from the Net (GAP, Macaulay 2, this sort of things).

Differential Geometry with Applications to General Relativity: 3 s.h.

- Key components: This course is intended to be a blend of Differential Geometry, Calculus of Variations and General Relativity.

- Course Outline:
 - I. Differential Geometry of Curves: Frenet Frames, Curvature, Torsion, Tautochrones etc.
 - II. Differential Geometry of Surfaces:
 - Charts and metric tensors
 - Parallel Transport, geodesics and angle sum formulae
 - Covariant derivatives
 - Gaussian curvature and the curvature tensor
 - Calculation of the curvature tensor for:
 - Planes, cylinders , torii and cones;
 - Spheres
 - Saddles
 - Rotated tractrix
 - Etc.
 - III. Calculus of Variations:
 - Extremal curves
 - The Euler-Lagrange Equations
 - Lagrangians in Physics
 - Trajectories of marbles rolling on a surface
 - The pendulum
 - Geodesics
 - Calculation of geodesics for all the surfaces in our repertoire.
 - IV. The General Theory of Relativity:
 - Gravity and the Principle of Equivalence
 - Spacetime
 - Minkowsky and Schwarzschild Geometries
 - Timelike curves, proper time
 - Time dilation in gravitational fields
 - Orbits of test particles
 - Bending of light rays and gravitational lensing
 - Kruskal-Szekeres Maximal Extension of Schwarzschild geometry
 - The Einstein-Rosen Wormhole
- Prerequisites: Differential Equations (Math 333).
- Faculty members who can teach this course: Anyone who spends the time to learn the material. The course is not intended to go beyond Masters level students.
- Software required for this class: None is really necessary for an explication of this material, though Maple could be used to make some of the calculations easier and to create illustrative graphics. I would warn the instructors that sometimes hand calculation is helpful to confirm definitions and concepts in the mind of the learner.

5.2. M5-M6/Math 699.

5.2.1. *Teaching Mathematics.*

Technology and the Secondary Mathematics Curriculum: 3 s.h.

- Course Outline:
 - I. Overview of the Technology and Instructional Issues

- A. Introduction to the Use of Calculators (including graphics calculators and computer algebra system (CAS) calculators)
- B. Introduction to the Use of Computers
 - 1. Basic principles, menus, and file management.
 - 2. Basics of electronic spreadsheets.
 - 3. Multimedia software.
 - 4. Software evaluation
- C. Introduction to Internet Use
 - 1. Navigation, search, and downloading basics.
 - 2. Creating a World Wide Web homepage.
 - 3. Internet site evaluation.
- D. Introduction to Planning for Instruction with Technology Issues
 - 1. Publications on the use of technology in the classroom.
 - 2. Research on the use of technology in the classroom.
 - 3. Classroom structure (including the one-computer classroom, multiple-computer classroom, computer lab use.)
 - 4. Presentation software.
- II. A Closer Look at Technology and Instructional Issues
 - A. Investigating Functions and Relations Using Technology
 - 1. Using calculators.
 - 2. Using computers. Maple, Function Explorer, WinPlot, Excel.
 - 3. Using the Internet.
 - 4. Planning for Instruction.
 - B. Investigating and Discovering Geometry Concepts Using Technology
 - 1. Using calculators. TI-92
 - 2. Using computers. Geometers' Sketchpad
 - 3. Using the Internet.
 - 4. Planning for Instruction.
 - D. Probability and Statistics (Data Analysis) Using Technology
 - 1. Using calculators.
 - 2. Using computers. Excel, Fathom.
 - 3. Using the Internet.
 - 4. Planning for Instruction.

Note that I - introduction makes up about 25% of the course. II makes up 75% of the course.

- Prerequisites: Permission of the instructor.
- Faculty members who can teach this course: Dr. Olsen and Dr. Mann
- Software required for this class: Geometer's Sketchpad, MS Office (Excel, Word, etc.), Maple, Fathom.

Teaching Trigonometry and AP Calculus: 3 s.h.

- Course Outline:
 - Analysis of various approaches to trigonometric functions (right triangle trigonometry, trigonometric functions, and circular functions).
 - Representations to illuminate trigonometry concepts (physical and electronic).
 - The AP Calculus syllabus (from the College Board) and exam study guides. This will make up a major portion of the course.

- The use of a Computer Algebra System and graphics calculator in the teaching of calculus.
- Representations to illuminate calculus concepts (physical and electronic).
- Applications of trigonometry and calculus.
- Pedagogical issues related to the teaching of trigonometry and calculus.
- Prerequisites: Minimum prerequisite is one semester of calculus. Two or more semesters of calculus preferred.
- Faculty members who can teach this course: Olsen, Mann, and Lawton have expressed interested, but many other faculty could teach the course.
- Software required for this class: Computer Algebra System on a calculator as per the required/allowed by the College Board for the AP Calculus Exam.

5.2.2. *Applied Mathematics/Numerical Analysis.*

Optimal Control with Elements of Mathematical Modeling: 3 s.h.

- Key components: Optimal Control/ Dynamical systems/Applications (to Financial Math)/Matlab
- Course Outline:
 - The Maximum Principle: Continuous Time
 - Maximum Principle: General Inequality Constraints
 - Applications to: Finance, Production and Inventory. Marketing
 - The Maximum Principle: Discrete Time
 - Applications to: Natural Resources, Maintenance and Replacement, Economics
 - Differential Games, Distributed Systems, and Impulse Control.
 - Stochastic Optimal Control
 - Calculus of Variations
 - Modeling in Engineering
 - Mathematical Model Developments
 - MATLAB and SIMULINK
 - Analysis and Control of Linear Dynamic Systems
 - Analysis, Identification and Control of Nonlinear Dynamic Systems
- Prerequisites: C2 or Math 311/333
- Faculty members who can teach this course: Dr. Andreev.
- Software required for this class: Matlab.

Mathematical Modeling: 3 s.h.

- Key components: Dynamical Systems/Optimal Control/Linear Programming/Optimization
- Course Outline:
 - Dynamical systems (with plenty of applications)
 - Equilibriums and limit cycles in the model
 - Optimal Control
 - Elements of probabilistic approach (and distributions)
 - Art of applying models
 - Linear programming
 - Optimization (including multivariable case)
- Prerequisites: Calculus, Math 311 (Linear Algebra), Math 333 (Ordinary Differential Equations)

- Faculty members who can teach this course: Dr. Andreev - anybody else who can/did teach 488, 583, or 589.
- Software required for this class: Matlab.

5.2.3. *Statistics.*

Theoretical Principles and Procedures of Statistics: 3 s.h. Topics among which to choose:

- I. Essentials of Probability
- II. Random Variables and Probability Distributions
- III. Normal Distributions
- IV. Estimation of Parameters for a Population
- V. Testing Parameters for a Population
- VI. Testing Parameters for Two Populations
- VI. Testing Parameters for more than Two Populations
- VII. Analysis of Variance I: The One-Way Classification
- VIII. Multiple Comparisons
- IX. Principles of Experimental Design
- X. Analysis of Variance II: Multiway Classifications
- XI. Linear Regression of Single Explanatory Variable
- XII. Multiple Regression
- XIII. Correlational Analysis
- XIV. Analysis of Covariance
- XV. Chi-Square Analysis
- XVI. Contingency Tables
- XVII. Nonparametric Statistics
- XVIII. Elementary Multivariate Statistical Analysis
- XIX. Elements of Statistical Process Control
- XX. Elementary Time Series Analysis

The educational approach of this course is to study the theoretical foundations for the use of statistical software to introduce many types of experimental situations to which statistical solutions are obtained by use of software. The problem's solution, once determined by the software routine, is then the basis of learning the theoretical constructs of the problem, the theoretical assumptions for such a solution, and the evaluation and interpretation of the solution on the basis of the theory. Therefore, a successful student will not only learn how to use statistical software, but the example problems and their statistical solutions will provide the emphasis for learning statistical theory, as emphasis, for the procedures and their interpretations.

The particular statistical software is not so much of importance but the obvious choices of SPSS, SAS, or S-Plus are readily available examples from which to choose.

A textbook probably is as important as is the need to find a good manual that describes the various statistical routines in the computer software. An example of such a manual would be the SPSS 10.0 Guide to Data Analysis by Marija J. Norusis (Prentice Hall; ISBN 0-13-0029204-4) or its equivalent for other software. An example of textbooks for such a course which incorporate statistical theory such as Linear Models in Statistics, by Alvin C. Rencher (Wiley; ISBN 0-471-31564-8); Applied Multivariate Statistical Analysis, by Richard A. Johnson & Dean W. Wichern (Prentice Hall; ISBN 0-13-041146-9).

5.2.4. *PhD Track.***Real Analysis: 3 s.h.**

- Course Outline: The course will cover the following core material in addition to other topics (e.g. Harmonic Analysis, etc) as time permits and depending on the students' interests
 - Introduction
 - * Continuous Functions
 - * Riemann Integrals
 - * Functions of Bounded Variation
 - * Riemann - Stieltjes Integrals
 - Lebesgue Measure
 - * Outer Measure on \mathbb{R}
 - * Measurable Sets and their Properties
 - * a non Measurable Set
 - * Cantor Sets
 - Lebesgue Measurable Functions
 - * Elementary Properties
 - * Littlewood's Three Principles
 - Lebesgue Integration
 - * Definition of the Integral
 - * Convergence Theorems
 - * Comparing Riemann and Lebesgue Integrals
 - * $L_p(\mathbb{R})$
- Prerequisites: Math 435 or equivalent
- Faculty members who can teach this course: Any graduate faculty with interest in Analysis (e.g. John Chisholm, Boris Petracovici, Lia Petracovici, Khodr Shamseddine, Nader Vakil, Galen Weitkamp, Larry Welch, etc)
- Software required for this class: None.

Complex Analysis: 3 s.h.

- Course Outline: Cauchy Theorem, Identity Principle, Liouville's Theorem, Maximum Modulus Theorem, Cauchy Formula, Residue Theorem, Rouché's Theorem, Casorati-Weierstrass Theorem, Arzela-Ascoli Theorem, Conformal Mapping, Schwarz Lemma, Riemann Mapping Theorem.
- Prerequisites: Math 435 or equivalent
- Faculty members who can teach this course: Any graduate faculty with interest in Analysis (e.g. John Chisholm, Boris Petracovici, Lia Petracovici, Khodr Shamseddine, Nader Vakil, Galen Weitkamp, Larry Welch, etc)
- Software required for this class: None.

5.2.5. *Open.***Set Theory and Point-Set Topology: 3 s.h.**

- Key components: This course is intended to be a blend of set theory and point-set topology.
- Course Outline:
 - I. The Foundations of Set Theory: Discussion of the origins and axioms of the theory of sets from extension to replacement.
 - II. The Theory of Ordinal Numbers:
 - Well-founded and well-ordered sets.

Induction and recursion on well-founded partial orders.

Von Neumann ordinals

The axiom of choice is equivalent to every set can be well-ordered.

The axiom of choice is equivalent to every vector space has a basis.

III. Theory of Cardinal Numbers:

Countable vs uncountable sets.

Existence of irrationals and transcendental numbers.

The sequence of beth numbers.

Cardinal numbers.

The sequence alephs.

Some simple cardinal arithmetic with the aid of choice.

IV. Point-set topology:

Definition of a topological space.

Complete metric spaces.

Borel Sets.

Perfect sets and the Continuum Hypothesis.

Cantor derivative and its transfinite iterations.

The perfect set theorem.

Gale-Stewart and related games.

Perfect Sets and the Axiom of Determinacy.

The ordinal lengths of a descending nest of closed sets.

k-scales

Lusin's Set and the Continuum Hypothesis.

Compactness and finite products of compact sets.

Equivalence of the axiom of choice to Tychonoff's theorem.

- Prerequisites: Perhaps Math 441 or a demonstrated ability to follow and compose proofs.
- Faculty members who can teach this course: Anyone who spends the time to learn the material. The course is not intended to go beyond Masters level students. However, the logicians in the department are well posed to dive right in.
- Software required for this class: None, though Tarski's World might be fun to use for a few demonstrations of formal proof. The proofs in this course, however, should not be formal nor framed in a formal language. The students should be convinced that a translation into the formal realm is always possible.

Multivariate and Complex Analysis with Applications to Fluid Mechanics: 3 s.h.

- Key components: Complex Analysis and Multivariate Analysis
- Course Outline:
 - I. The Definition and Meaning of Divergence, Gradient and Curl using fluid flow as an illustration of the ideas. Discuss Incompressible flow, the conservation of mass and it their relation to divergence. Discuss potential flows and gradients. Discuss curl, vortices, vortex lines and sheets and Kelvin's circulation theorem.
 - II. The Basics of Complex Calculus: Euler's equation, Cauchy's criteria for analyticity, Cauchy's integral formula, the residue theorem.
 - III. Potential Flows in two dimensions utilizing the complex plane.

- Prerequisites: The undergrad calculus sequence and 311.
- Faculty members who can teach this course: Anybody
- Software required for this class: None.

6. APPENDIX B [2003-2004 PROGRAM REVIEW]

6.1. Program Goals.

- Prepare students for different careers, ranging from teaching and industrial positions to entering a Ph.D. program.
- Offer students a wide range of program options to prepare them for the job market.

6.2. **Student Learning Outcomes.** Upon completion of the program students will have a solid mathematical foundation in order to use their knowledge in teaching and real-world applications, or to pursue doctoral studies.

6.3. Relevant Contextual Information.

- The average enrollment for the last five years was 13.6 with increasing numbers for the last three years. The average number of degrees awarded per year for the last five years was 4.8, and 7 for the last two years.
- For the Fall 2004, the Department has admitted 13 new students, 4 of these are American while the rest are from many different countries.
- The average number of years to complete the degree was 2.3 for the period of Fall 1998 - Summer 2003. The average for the university for the same period was 2.7.
- Of the 11 respondents to an alumni questionnaire, 4 have continued their graduate studies, 4 have worked as school teachers, and 3 as instructors at colleges.
 - Seven find the graduate training that they received at Western to be 'very relevant' to their present job and four find it 'somewhat relevant'.
 - All would recommend the program.
 - Their average ranking for both the quality of the graduate faculty and intellectual stimulation received from them, is 4.6 where 5 is the highest, and 1 the lowest.
 - The average ranking of the quality of preparation for job/further education is 4.5 on the scale of 1-5 where 5 is the highest.

6.4. Actions Taken Since Last Review.

- The Department approved development of new programs that will offer a solid core and then a variety of options, some in collaboration with other departments. This will improve students' chances for a successful career.
- The Graduate Committee has discussed ways to begin a new program in applied mathematics both in Macomb and in Quad Cities. This could be one of the university's strategic goals and also one of the Illinois agenda for higher education - "Higher education will help Illinois business and industry sustain strong economic growth."
- Possibilities of implementing a program in financial mathematics have been discussed with various department chairs.

- Possible cooperation regarding a Masters degree for secondary teachers, strong in content and pedagogy, was discussed with the chair of Educational and Interdisciplinary Studies.
- In anticipation of the new programs, the Department has encouraged the offering of new "blend" courses that would eventually evolve into regular courses.
- Six new faculty have been hired in Spring 2003 and two more in Spring 2004, among them two statisticians and three in applied mathematics.
- Faculty continued to be active in research. There were 129 publications, 156 presentations, 32 grants, 5 student publications and 10 student presentations.
- The Graduate Committee approved a change in admission requirements and application for assistantship. The general part of GRE will be recommended for admission and required for receiving an assistantship.
- The Department has received a recruitment fund award that will pay for a list of prospective students who take the GRE and who could be pursued to apply for admission.

6.5. Major Findings.

- According to the US Department of Labor, "there will be continued strong demand in professions that require solid background in mathematics."
- The US Department of Labor also gives a good employment picture for teaching jobs. "Opportunities for college and university teaching jobs are expected to improve", "Overall, employment of postsecondary teachers is expected to grow much faster than the average for all occupations through 2012.

The revision of our graduate program will, with support from the university, better prepare students for these expanding job opportunities.

6.6. Recommendations.

- Build on the existing strengths to develop new programs that will train students for professions with positive employment outlook.
- Establish ties with regional industries through cooperation and internships to help create demand for our graduates.

6.7. Actions Planned.

- Pursue the development of new programs and establish ties with regional industries through cooperation and internships.
- Expand the recruitment efforts through the GRE Search Service.
- Work closely together with the undergraduate program to recruit our better undergraduate students for the graduate program.

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