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1 Academic Year 2014–2015 Calendar

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<thead>
<tr>
<th>Fall Semester</th>
<th>Spring Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program of Studies forms for new students due</td>
<td>Spring Graduation Applications for MA and PhD due</td>
</tr>
<tr>
<td>August 22</td>
<td>Holiday: Martin Luther King Jr. Day</td>
</tr>
<tr>
<td>August 20–22</td>
<td>Spring Vacation</td>
</tr>
<tr>
<td>August 20–22</td>
<td>March 16 Summer Graduate Research Scholarship applications due</td>
</tr>
<tr>
<td>August 25</td>
<td>March 30–April 3</td>
</tr>
<tr>
<td>First Day of Classes</td>
<td></td>
</tr>
<tr>
<td>November 4</td>
<td>May 8</td>
</tr>
<tr>
<td>Holiday: Labor Day</td>
<td>Winter Graduation Applications for MA and PhD due</td>
</tr>
<tr>
<td>November 11</td>
<td>May 11–15</td>
</tr>
<tr>
<td>Holiday: Election Day</td>
<td>Final Examinations</td>
</tr>
<tr>
<td>November 26–28</td>
<td>May 16</td>
</tr>
<tr>
<td>Thanksgiving Vacation</td>
<td>Commencement</td>
</tr>
<tr>
<td>December 9–12</td>
<td>June 19</td>
</tr>
<tr>
<td>Final Examinations</td>
<td>Final deadline for completion of all requirements for spring graduation</td>
</tr>
<tr>
<td>December 30</td>
<td></td>
</tr>
</tbody>
</table>
## 2 Graduate Faculty

### 2.1 Research Groups

| Algebra          | Kelly McKinnie  
|                 | Nikolaus Vonessen  
| Combinatorics & Optimization | Mark Kayll  
|                 | Jennifer McNulty  
|                 | George McRae  
|                 | Cory Palmer  
| Analysis        | Jennifer Halfpap  
|                 | Greg St. George  
|                 | Karel Stroethoff  
|                 | Thomas Tonev  
| Mathematics      | James Hirstein  
|                 | Ke Norman  
|                 | Matt Roscoe  
|                 | Bharath Sriraman  
| Applied Mathematics | John Bardsley  
|                 | Leonid Kalachev  
|                 | Emily Stone  
| Statistics       | Jonathan Graham  
|                 | David Patterson  
|                 | Brian Steele  
|                 | Solomon Harrar  
| Topology         | Eric Chesebro  

### 2.2 Graduate Faculty

<table>
<thead>
<tr>
<th>Name</th>
<th>Degree, University</th>
<th>Research interest(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>John Bardsley</td>
<td>Ph.D., Montana State University</td>
<td>numerical analysis</td>
</tr>
<tr>
<td>Eric Chesebro</td>
<td>Ph.D., University of Texas at Austin</td>
<td>geometric topology</td>
</tr>
<tr>
<td>Jonathan Graham</td>
<td>Ph.D., North Carolina State University</td>
<td>statistics, spatial statistics</td>
</tr>
<tr>
<td>Jennifer Halfpap</td>
<td>Ph.D., University of Wisconsin</td>
<td>several complex variables, harmonic analysis</td>
</tr>
<tr>
<td>Solomon Harrar</td>
<td>Ph.D., Bowling Green State University</td>
<td>multivariate analysis</td>
</tr>
<tr>
<td>James Hirstein</td>
<td>Ed.D., University of Georgia</td>
<td>mathematics education</td>
</tr>
<tr>
<td>Leonid Kalachev</td>
<td>Ph.D., Moscow State University</td>
<td>asymptotic methods, math biology</td>
</tr>
<tr>
<td>Mark Kayll</td>
<td>Ph.D., Rutgers University</td>
<td>discrete mathematics</td>
</tr>
<tr>
<td>Kelly McKinnie</td>
<td>Ph.D., University of Texas at Austin</td>
<td>finite dimensional division algebras, the Brauer group, valuation theory &amp; algebraic geometry</td>
</tr>
<tr>
<td>Jennifer McNulty</td>
<td>Ph.D., University of North Carolina</td>
<td>matroid theory, combinatorics</td>
</tr>
<tr>
<td>George McRae</td>
<td>Ph.D., University of Washington</td>
<td>optimization, categorical algebra</td>
</tr>
<tr>
<td>Ke Norman</td>
<td>Ph.D., University of Minnesota</td>
<td>mathematics education</td>
</tr>
<tr>
<td>Cory Palmer</td>
<td>Ph.D., Central European University</td>
<td>graph colorings, extremal set systems &amp; applied problems in graph theory</td>
</tr>
<tr>
<td>David Patterson</td>
<td>Ph.D., University of Iowa</td>
<td>applied statistics</td>
</tr>
<tr>
<td>Matt Roscoe</td>
<td>Ph.D., University of Montana</td>
<td>mathematics education</td>
</tr>
<tr>
<td>Bharath Sriraman</td>
<td>Ph.D., Northern Illinois University</td>
<td>mathematics education</td>
</tr>
<tr>
<td>Brian Steele</td>
<td>Ph.D., University of Montana</td>
<td>applied statistics, statistical ecology</td>
</tr>
<tr>
<td>Greg St. George</td>
<td>Ph.D., University of Montana</td>
<td>functional analysis</td>
</tr>
<tr>
<td>Emily Stone</td>
<td>Ph.D., Cornell University</td>
<td>dynamical systems, applied mathematics</td>
</tr>
<tr>
<td>Karel Stroethoff</td>
<td>Ph.D., Michigan State University</td>
<td>complex and functional analysis, operator theory</td>
</tr>
<tr>
<td>Thomas Tonev</td>
<td>Ph.D., Moscow State University</td>
<td>functional and complex analysis, uniform algebras</td>
</tr>
<tr>
<td>Nikolaus Vonessen</td>
<td>Ph.D., Massachusetts Institute of Technology</td>
<td>noncommutative rings and invariant theory, division algebra</td>
</tr>
</tbody>
</table>
3 Communications

3.1 Mail room

The mail room is in room MA 101. Every graduate student has a mailbox, and it is important that this mailbox be checked periodically, since materials that may require timely responses will be distributed to graduate student mailboxes.

3.2 Email

In addition to written notices in mailboxes, electronic notices by email will be sent from time to time. It is your responsibility to keep your email address current, and to check it periodically. You can obtain a university email account from Information Technology (formerly CIS) or use an account from an external email provider. You are automatically assigned a “umontana” email address (this is of the form first.last@umontana.edu, where ‘first’ and ‘last’ are your first and last name). It is strongly recommended that you sign up to use a “umontana” email address through Cyberbear. The “umontana” email address is not another email account, but rather a pointer or alias to an email account of your choice. Use of an “umontana” address has the advantage that you can keep using the same address even if you change email accounts.

3.3 Graduate Committee

Current Graduate Committee:

- Jennifer Halfpap Kacmarcik, Graduate Chair, halfpap@mso.umt.edu
- Eric Chesebro
- James Hirstein
- Brian Steele
- Emily Stone
- Ke Wu

Administrative assistance:

- Linda Azure
  - Phone 243-5312
  - Email: azure@mso.umt.edu

3.4 Webpage

Information for current students (including all graduate forms) can be found at the following web page:
http://cas.umt.edu/math/graduate/.

4 Transfer Credits

4.1 Master’s Degree Program

Students may transfer up to nine graduate/graduate non-degree semester credits or a full semester of graduate work on the recommendation of the program, after a semester of
satisfactory work at UM. The 9 credit limit may be exceeded with recommendation from the program and approval from the grad school. The transfer credits must meet the following requirements:

1. The courses must have been taken for graduate credit. This information is verified by the Graduate School when the student submits a transcript of the transfer coursework.

2. Grades must be either an A or a B.

3. Credits must be earned at an institution that offers a graduate degree in the discipline of the course being transferred.

4. Credits must be applicable to the degree being sought.

5. The transfer request form is available on-line. Please complete the form and submit to the Graduate Chair.

4.2 PhD Degree Program

On the recommendation of the department and approval of the Graduate Dean, credits may be transferred (including an entire Master's Degree and/or credits from a Master's Degree program) from other institutions after a semester in residence.

Credits with grades other than A or B, thesis or correspondence credits, extension credits outside the Montana university system, or credits earned at institutions not offering graduate degrees in the discipline of the course are not transferable.

Graduate transfer credits are added to a student's record only if the student is in a graduate degree program and if the credit is applicable to the degree being sought.

Note. Since transfer credits must be applicable to the degree being sought, the Graduate Committee will only approve of transfer credits for courses offered through our graduate program. A request for transfer credits needs to include a listing of the courses at UM which are to be considered equivalent to the transfer credits. The transfer request form is available on-line.

5 Graduate Student Travel

5.1 Graduate School Student Travel Policy
The Graduate School allocates funds for graduate student travel (last academic year $10,000 was available for this purpose). Awards are available for graduate students intending to give talks/papers at professional meetings. Graduate students can receive a travel award only once per academic year, and they can apply only for the period in which a paper is presented. Graduate students can apply for travel money if their papers are “pending acceptance” but must verify acceptance before the award is funded. Students are generally eligible to receive one travel award at the master’s level and one at the doctoral level. Doctoral students who did not receive a travel award at the master’s level are eligible for two awards at the doctoral level. Application needs to be made by the Graduate Program of the student’s department. There will be several calls (last year there were three) to apply for these travel funds.

5.2 Departmental Graduate Student Travel Policy

Graduate Students in the Department of Mathematical Sciences may request travel funds for professional meetings. Requests will be considered by the Policy Committee and allocated on the following basis:

1. The Policy Committee will allocate funds and determine maximum reimbursement levels each year. Unused funds from fall semester will be made available for spring requests.

2. Up to the maximum level determined, the Department will provide $2 for each $1 the student contributes from personal and/or other sources. The departmental allocation will be more for students presenting papers, but students may request funding for participation.

The Policy Committee has allocated $2500 for each semester of the academic year, and maximums of up to $600 for a student presenting a paper, and up to $400 for participation if no presentation is given. Requests for travel money should be submitted to the Graduate Program Chair prior to travel. While it is possible to receive funding for more than one trip in an academic year, preference will be giving to applicants requesting funding for the first trip.

6 Graduate Student Scholarships and Fellowships

6.1 Graduate School Scholarships and Fellowships

Bertha Morton Fellowships and Scholarships
Award amounts are $2000 and $3000, respectively. Nomination documentation and recommendations should be based on the student’s academic record and accomplishments in one or more of the following areas:

- Honors and awards
- Professional certifications and credentials
- Evidence of research and other academic achievements
- Evidence of professional and community achievements
- Additional achievements and creative activities

Our Graduate Program may nominate up to two graduate students for these awards. The Graduate Committee will select the students who will be nominated. Application for these awards is in February, you will get an announcement in January.

6.2 Departmental Scholarships

Summer Graduate Research Scholarships in Mathematical Sciences

Award amount: up to $3200 per award. Any graduate student in the Department of Mathematical Sciences may apply. Preference will be given to graduate students in the Ph.D. program, especially students who have passed their preliminary exams, but strong applicants in the Master’s program are also encouraged to apply. Applicants are requested to submit an application containing the following data: sketch of applicant’s background (place of origin, schools attended, degrees, etc.), list of all courses and seminars taken at UM, including names of professors and grades, list of examinations taken (with dates), future academic plans (including courses, seminars and examinations the applicant is planning to take), a narrative detailing the applicant’s research plans for the summer during which support is requested sponsored by a departmental faculty member, other pertinent information (publications, presentations, etc.). Application for these awards will be made in March. You will get a call for applications in the spring.
7 MA Comprehensive/PhD Preliminary Exams

The written MA Comprehensive/PhD Preliminary Examinations are closed-book exams in which students are not allowed to bring notes prepared in advance. However, the Examination Committee is allowed to include, as part of an exam, anything (for example, tables) that the committee deems necessary for students to have while taking the exam. The following pages contain descriptions of the MA Comprehensive/PhD Preliminary Examinations in each of the subject areas. Old exams are available in the Math Office.

Preliminary exam exemption

Students who completed their MA degree in the department before entering the PhD program can be exempted from a preliminary exam in the area of their MA emphasis if they performed exceptionally well on the MA comprehensive exam, receiving a pass at the PhD level.

7.1 Algebra

The key topics for the graduate exam in algebra are:

**Prerequisites:** Properties of integers (e.g., division algorithm, the greatest common divisor as a linear combination, primes), mathematical induction, equivalence relations, elementary properties of functions (e.g., injective, surjective, bijective, invertible).

**Group Theory:** Subgroups, cyclic groups, examples of groups (e.g., symmetric groups, dihedral groups, \( \text{GL}_n \), \( \text{SL}_n \)), cosets, Lagrange’s Theorem, normal subgroups, factor groups, group homomorphisms and isomorphisms, isomorphism theorems, external and internal direct products, Fundamental Theorem of Finite Abelian Groups.

**Ring Theory:** Ideals, factor rings, ring homomorphisms, isomorphism theorems, integral domains, the field of quotients of an integral domain, prime and maximal ideals, principal ideal domains, polynomial rings (with emphasis on the case where the coefficients lie in a field or in the ring of integers), factorization of polynomials, irreducibility tests (including Eisenstein’s Criterion), Gauss’ Lemma.

**Linear Algebra and Vector Spaces:** Linear independence, bases, dimension, matrices, solving systems of linear equations, linear transformations, the matrix of a linear transformation with respect to two bases, rank, trace, elementary properties of
determinants, eigenvectors, eigenvalues, diagonalization.

**Field Theory**: Extension fields, roots of polynomials, adjunction of elements, splitting fields, algebraic and transcendental extensions, finite extensions, finite fields and their subfields.

Most of these topics are usually covered in the undergraduate algebra sequence Math 421/422, with the exception of some of the linear algebra topics, which you should have seen in your undergraduate linear algebra course. The exam does, however, require the maturity of reasoning expected from a graduate student. It is therefore strongly recommended to take at least one additional proof-oriented course (400-level or above, need not be in algebra) before taking the algebra exam. Taking the graduate algebra sequence is neither necessary nor required (although it certainly does help).

Some introductory books on Abstract Algebra:


To prepare for the linear algebra part of the exam, first read the relevant section on vector spaces in a textbook on abstract algebra. Then review the material from your undergraduate linear algebra class. A good proof-oriented reference for linear algebra (which contains much more material than covered on this exam) is the book


### 7.2 Analysis

Here are some of the key topics to be covered by the exam. The students are expected to demonstrate: (1) The ability to solve problems, combine, relate and utilize various of these topics, as well as other topics covered by all 400-(and lower-) level Analysis (also Calculus, Abstract Mathematics) courses offered at UM; (2) An understanding of the breadth and a substantial knowledge of mathematics topics and their deep interconnecting principles, and of the interplay among problem solving, theory, and applications; (3) An awareness of the abstract nature of theoretical mathematics and the ability to write proofs.

Though the exam is based on 400-level courses in Analysis, taking any particular 400-level course is not necessary nor sufficient for proper preparation. The exam should not be viewed as a “final examination” for a specific course.

A short list of literature, providing the essential material is included, which may be helpful in studying the topics for the exam, though it is not expected that the students will study all of the listed books before taking the test. Looking at exams from the past will be a good idea.

**Key Topics**

1. The real number system. Properties and basic theorems.
2. Theory of metric spaces and functions on them. Properties and basic theorems (including Baire category theorem, Banach fixed point theorem etc.).

3. Uniform convergence of functions. Relationship with continuity, differentiability, integration. Properties and basic theorems (including Weierstrass, Arzela-Ascoli theorems etc.).

4. Lebesgue integration. Properties and basic theorems (including Lebesgue dominated and other convergence theorems etc.).

5. Analytic functions, complex integration.

6. Singularities and applications to contour integration.


Recommended Reading


7.3 Applied Mathematics
Supplement to “Guide to Graduate Programs in Mathematical Sciences”

Topics:

**Ordinary Differential Equations:** solution techniques for initial and boundary value problems, linear theory (equations and systems), stability, numerical methods, power series methods, Sturm-Liouville theory, Laplace transform and Fourier series methods, matrix methods.

**Partial Differential Equations:** Method of characteristics, Heat, Wave, and Laplace equations, separation of variables method and orthogonality, Poisson integrals, maximum/minimum principles, Laplace transforms, traveling waves, Green’s functions.

**Modeling:** Linear and nonlinear difference and differential equations and systems, eigenvalues and eigenvectors, phase-planes, stability, and direction fields, elementary background in period doubling, bifurcation theory, and chaos.

**Numerical Analysis:** Basic techniques of solving ordinary and partial differential equations numerically, LU decomposition of matrices, QR and power methods of finding eigenvalues, the four linear spaces associated with a matrix (row and column space, kernel, cokernel), orthogonality of eigenspaces and numerical methods related to these concepts.

**Texts:**

1. Most of the topics mentioned under the headings of Ordinary Differential Equations, Partial Differential Equations, Linear Algebra, and Numerical Analysis can be found in any Advanced Engineering Mathematics text. For example:

2. Most of the topics mentioned as modeling appear in the following four references:
   - Steven H. Strogatz, Nonlinear Dynamics and Chaos, Westview Press
   - J. Guckenheimer & P. Holmes, Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields, Springer-Verlag, 1983.

### 7.4 Combinatorics & Optimization

**Outline of Topics for the M.A. Comprehensive/Ph.D. Preliminary Exam**

**Combinatorics**

1. enumeration (of the basic combinatorial objects: functions, permutations, subsets [combinations], multisets, set partitions [Stirling and Bell numbers], vector subspaces [Gaussian coefficients], compositions of integers, partitions of integers, etc.)
2. graph theory (trees, matchings, connectivity, Euler tours, Hamilton cycles, coloring, planarity, Ramsey theory, random graphs, algorithms)

3. directed graphs and networks (tournaments, max-flow min-cut theorem, Menger’s theorem, matrix-tree theorem)

4. combinatorial theory (double-counting, generating functions, pigeonhole principle, inclusion-exclusion, systems of distinct representatives, extremal set theory)

5. combinatorial structures (set systems [families of sets, hypergraphs], matroids, designs, finite geometries, partially ordered sets, codes)

**Optimization**

1. convexity (hyperplanes, convex sets, polytopes, polyhedra)

2. linear programming algorithms (geometric approach, simplex and revised simplex methods, dual simplex method, primal-dual algorithm, network simplex method, interior point methods, computational complexity)

3. duality theory, complementary slackness, sensitivity analysis

4. integer programming (transportation, assignment and transshipment problems, network flow problems, integrality theorems, branch-and-bound)

5. graph optimization algorithms (minimum spanning tree, shortest path, maximum [weighted] matching, PERT)

**Suggested Reading**

- *Linear Programming*, Chvatal, Freeman 1983
- *A Course in Combinatorics*, van Lint & Wilson, Cambridge 1992
- *Introduction to Graph Theory, 2nd Ed.*, West, Prentice-Hall 2001

**Remarks:** These topics are typically covered in the 300- and 400-level Combinatorics and optimization courses. Students are expected to demonstrate proficiency beyond the introductory level presented in these courses. Thus, to pass the examination, it is neither sufficient nor necessary to take these courses. Likewise, there are many good texts that may be consulted in addition to, or in place of, those on the list above. As a guiding principle, appropriately prepared students should expect to demonstrate insight and sophistication appropriate for graduate-level work.

**7.5 Mathematics Education**

Topics for this exam may be chosen from section (a) or sections (a) & (b).
(a) Mathematics Content. Students are expected to demonstrate proficiency in topics typically covered in 300–400 level courses such as Algebra/Geometry, Probability & Statistics, Number Theory, Mathematical Modeling and History of Mathematics. Topics for potential exam questions include the following:

- Algebraic structure of the real numbers and subsets of that systems.
- Equivalence relations and equivalence classes.
- High school concepts extending from the ring of polynomials.
- Concepts in mathematics related to Euclidean constructions.
- Transformation groups of isometries.
- Logic of proofs.
- Transfinite numbers.
- Diophantine equations and their relation to geometric concepts.
- Congruences and modular arithmetic.
- Measures of central tendency and dispersion.
- Probability distributions.
- Mathematical modeling.
- Historical development of specific topics (for example, the limit).

Texts used recently


(b) Mathematics Pedagogy. Students are expected to demonstrate literacy on the theories of learning and teaching of mathematics as well as literature on curriculum, evaluation and philosophy of mathematics education. Students are also expected to have had experience reading and critically evaluating original research, and to have developed an awareness of and an appreciation for various qualitative and quantitative research methods in mathematics education.
Suggested Readings:


Additional readings may include: a selection of articles from various math-ed journals, readings on the history of reform.

7.6 Statistics

The MA Comprehensive and PhD Preliminary Examinations in Statistics are based on the material in a standard course in Mathematical Statistics at the undergraduate level. Students taking this exam are assumed to have a fairly complete mastery of this material. The lists below contain topics for the exam and titles of a number of standard mathematical statistics textbooks that could be used to prepare for these exams. Any one of these books would be quite satisfactory. The material on the examination can also be found in the course Math 441–2. The exams will also have a take home computer component where you will be asked to run a statistical analysis on some data using at least one piece of statistical software.

Possible topics for the Statistics examinations:

1. Probability
   - Sample spaces, events, probability axioms
   - Counting techniques
   - Conditional probability, independent events
   - Discrete and continuous sample spaces

2. Random Variables
   - Probability distributions for random variables
   - Distribution functions and density functions
   - Expected values, moments and generating functions
   - Functions of random variables
3. Particular discrete and continuous probability models
   (a) Bernoulli and Binomial
   (b) Geometric and Negative Binomial
   (c) Hypergeometric
   (d) Poisson
   (e) Uniform, Exponential and Gamma
   (f) Beta and Normal

4. Jointly distributed random variables
   (a) Vector random variables
   (b) Conditional distributions and independence
   (c) Expected values, moments, sums of random variables
   (d) Chebyshev’s inequality and the law of large numbers
   (e) The central limit theorem
   (f) Multinomial, bivariate normal, t, F, chi-square distributions
   (g) Order statistics

5. Methods for deriving probability distributions for random variables
   (a) Distribution function technique
   (b) Change of variable technique
   (c) Moment generating function technique

6. Descriptive statistics and graphical displays
   (a) Sample mean and variance, median, percentiles, range, interquartile range
   (b) Histograms, stem and leaf plots, boxplots, probability or quantile plots

7. Estimation of parameters
   (a) Methods of moments and maximum likelihood
   (b) Properties of estimators
   (c) Confidence interval estimation
8 Graduate Courses for the Academic Year

The following table contains the graduate courses and seminars scheduled to be offered during Fall semester; it also lists 400-level undergraduate courses that graduate students may take for graduate credit (UG courses).

8.1 Fall Semester 2014

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>CRN</th>
<th>Room</th>
<th>Days</th>
<th>Time</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UG Courses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STAT 421</td>
<td>Probability Theory</td>
<td>72569</td>
<td>MATH 306</td>
<td>MWF</td>
<td>10:10-11:00</td>
<td>Brian Steele</td>
</tr>
<tr>
<td>M 431</td>
<td>Abstract Algebra I</td>
<td>70140</td>
<td>MATH 211</td>
<td>MTWF</td>
<td>1:10-2:00</td>
<td>Nikolaus Vonessen</td>
</tr>
<tr>
<td>M 439</td>
<td>Euclidean &amp; Non-Euclidean Geo</td>
<td>70354</td>
<td>MATH 306</td>
<td>MWF</td>
<td>12:10-1:00</td>
<td>James Hirstein</td>
</tr>
<tr>
<td>M 440</td>
<td>Numerical Analysis</td>
<td>74885</td>
<td>MATH 306</td>
<td>MTWF</td>
<td>11:10-12:00</td>
<td>John Bardsley</td>
</tr>
<tr>
<td>M 445 - 01</td>
<td>Stat/Math/Comp Modeling</td>
<td>73163</td>
<td>MATH 306</td>
<td>MTWF</td>
<td>1:10-2:00</td>
<td>Leonid Kalachev</td>
</tr>
<tr>
<td>M 445 - 50</td>
<td>Stat/Math/Comp Modeling</td>
<td>74343</td>
<td>WWW</td>
<td></td>
<td></td>
<td>Leonid Kalachev</td>
</tr>
<tr>
<td>M 491 - 01</td>
<td>Practical Big Data Analytics</td>
<td>73633</td>
<td>MATH 306</td>
<td>R</td>
<td>2:10-5:00</td>
<td>Brian Steele</td>
</tr>
<tr>
<td>M 491 - 02</td>
<td>ST: Theoretical Big Data Analy</td>
<td>75312</td>
<td>MATH 306</td>
<td>W</td>
<td>2:10-5:00</td>
<td>Peter Golubtsov</td>
</tr>
<tr>
<td>M 491 - 50</td>
<td>Practical Big Data Analytics</td>
<td>75345</td>
<td>WWW</td>
<td></td>
<td></td>
<td>Brian Steele</td>
</tr>
<tr>
<td>M 491 - 51</td>
<td>ST: Theoretical Big Data Analy</td>
<td>75346</td>
<td>WWW</td>
<td></td>
<td></td>
<td>Peter Golubtsov</td>
</tr>
<tr>
<td><strong>Graduate Courses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 511</td>
<td>Adv Math Methods</td>
<td>74886</td>
<td>MATH 108</td>
<td>MWF</td>
<td>12:10-1:00</td>
<td>Emily Stone</td>
</tr>
<tr>
<td>M 524</td>
<td>Topics in Algebra</td>
<td>74887</td>
<td>MATH 305</td>
<td>MWF</td>
<td>10:10-11:00</td>
<td>Kelly McKinnie</td>
</tr>
<tr>
<td>STAT 549</td>
<td>Applied Sampling</td>
<td>74888</td>
<td>MATH 211</td>
<td>MWF</td>
<td>2:10-3:00</td>
<td>David Patterson</td>
</tr>
<tr>
<td>M 551</td>
<td>Real Analysis</td>
<td>74889</td>
<td>MATH 311</td>
<td>MWF</td>
<td>11:10-12:00</td>
<td>Thomas Tonev</td>
</tr>
<tr>
<td>M 582</td>
<td>Optimization</td>
<td>74890</td>
<td>MATH 108</td>
<td>TR</td>
<td>9:40-11:00</td>
<td>Mark Kayll</td>
</tr>
<tr>
<td>M 595</td>
<td>ST: Differential Topology</td>
<td>74365</td>
<td>MATH 103</td>
<td>MWF</td>
<td>9:10-10:00</td>
<td>Eric Chesebro</td>
</tr>
<tr>
<td><strong>Seminars</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 504</td>
<td>Math Ed Seminar</td>
<td>73829</td>
<td>MATH 206</td>
<td>T</td>
<td>11:10-12:00</td>
<td>James Hirstein</td>
</tr>
<tr>
<td>M 600</td>
<td>Colloquium</td>
<td>70142</td>
<td>MATH 103</td>
<td>M</td>
<td>3:10-4:00</td>
<td></td>
</tr>
<tr>
<td>M 610</td>
<td>Gr Sem in Applied Math</td>
<td>70338</td>
<td>MATH 211</td>
<td>T</td>
<td>3:10-4:00</td>
<td></td>
</tr>
<tr>
<td>M 620</td>
<td>Graduate Seminar in Algebra</td>
<td>70143</td>
<td>MATH 211</td>
<td>T</td>
<td>4:10-5:00</td>
<td>Kelly McKinnie</td>
</tr>
<tr>
<td>STAT 640</td>
<td>Gr Sem Prob &amp; Stats</td>
<td>72520</td>
<td>MATH 211</td>
<td>T</td>
<td>3:10-4:00</td>
<td></td>
</tr>
<tr>
<td>M 650</td>
<td>Gr Sem in Analysis</td>
<td>70339</td>
<td>MATH 311</td>
<td>W</td>
<td>4:10-5:00</td>
<td>Thomas Tonev</td>
</tr>
<tr>
<td>M 680</td>
<td>Grad Sem Combin and Optim</td>
<td>71198</td>
<td>MATH 211</td>
<td>W</td>
<td>3:10-4:00</td>
<td>Mark Kayll</td>
</tr>
<tr>
<td>M 694</td>
<td>College Teaching Seminar</td>
<td>70345</td>
<td></td>
<td></td>
<td></td>
<td>Halfpap/Stone</td>
</tr>
</tbody>
</table>
# 8.2 Spring Semester 2015

The listings for Spring semester are tentative. For more information regarding these courses, consult course announcements, catalog descriptions, or the instructor.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Time</th>
<th>Days</th>
<th>Room</th>
<th>Instructor</th>
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<tbody>
<tr>
<td><strong>UG Courses</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 412</td>
<td>Partial Differential Equations</td>
<td>9</td>
<td>MWF</td>
<td>MA305</td>
<td>Stone</td>
</tr>
<tr>
<td>M 414</td>
<td>Deterministic Models</td>
<td>1</td>
<td>MWF</td>
<td>MA312</td>
<td>Bardsley</td>
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<tr>
<td>STAT 422</td>
<td>Mathematical Stats</td>
<td>10</td>
<td>MWF</td>
<td>MA306</td>
<td>Graham</td>
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<tr>
<td>M 429</td>
<td>History of Math</td>
<td>12</td>
<td>MWF</td>
<td>MA103</td>
<td>Roscoe</td>
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<tr>
<td>M 432</td>
<td>Abstract Algebra II</td>
<td>1</td>
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<td>MA108</td>
<td>Vonessen</td>
</tr>
<tr>
<td>M 472</td>
<td>Complex Analysis</td>
<td>11</td>
<td>MTWF</td>
<td>MA312</td>
<td>Tonev</td>
</tr>
<tr>
<td>M 491</td>
<td>ST: Big Data Projects</td>
<td>2-5</td>
<td>R</td>
<td>MA306</td>
<td>Steele</td>
</tr>
<tr>
<td><strong>Graduate Courses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 512</td>
<td>Topics in Applied Math II</td>
<td>11</td>
<td>MWF</td>
<td>MA108</td>
<td>Stone</td>
</tr>
<tr>
<td>M 524</td>
<td>Topics in Algebra</td>
<td>10</td>
<td>MWF</td>
<td>MA306</td>
<td>McKinnie</td>
</tr>
<tr>
<td>STAT 543</td>
<td>Multivariate Stat Analysis</td>
<td>2</td>
<td>MWF</td>
<td>MA211</td>
<td>Steele</td>
</tr>
<tr>
<td>M 555</td>
<td></td>
<td>12</td>
<td>MWF</td>
<td>MA108</td>
<td>Halfpap</td>
</tr>
<tr>
<td>M 584</td>
<td>Topic?</td>
<td>2</td>
<td>MWF</td>
<td>MA108</td>
<td>Palmer</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M 504</td>
<td>Math Ed</td>
<td>1</td>
<td>T</td>
<td>MA306</td>
<td>Sriraman</td>
</tr>
<tr>
<td>M 600</td>
<td>Colloquium</td>
<td>3</td>
<td>M</td>
<td>MA103</td>
<td></td>
</tr>
<tr>
<td>M 610</td>
<td>Applied Math (share time w/STAT640)</td>
<td>3</td>
<td>T</td>
<td>MA211</td>
<td>Stone</td>
</tr>
<tr>
<td>M 620</td>
<td>Algebra</td>
<td>4</td>
<td>T</td>
<td>MA211</td>
<td>Vonessen</td>
</tr>
<tr>
<td>STAT 640</td>
<td>Statistics (share time w/M610)</td>
<td>3</td>
<td>T</td>
<td>MA211</td>
<td>Steele</td>
</tr>
<tr>
<td>M 650</td>
<td>Analysis</td>
<td>4</td>
<td>W</td>
<td>MA211</td>
<td></td>
</tr>
<tr>
<td>M 680</td>
<td>C&amp;O</td>
<td>3</td>
<td>W</td>
<td>MA108</td>
<td>Palmer</td>
</tr>
</tbody>
</table>
9 Transition from Master’s to PhD Program

Acceptance into the PhD program after completing a master’s degree in our program is not automatic: an application needs to be submitted, and some of the application materials that were used to gain admission into the master’s degree program should be updated. The Graduate School requires an on-line application form. In addition, the Graduate Committee requires an updated statement of purpose, unofficial transcript and three reference letters from faculty from our program. The Graduate Committee will also want to see how a student’s proposed doctoral program fits in with the work done as part of the student’s master’s degree program. Master’s degree students who have entered with deficient background for a PhD degree in our program should take course work that will remedy these deficiencies before entering the PhD program.

10 Research credits for a PhD program

A total of 60 credits is required for a PhD. The appropriate course number for dissertation research is Math 699. Since Math 699 is repeatable for up to 9 credits (see Catalog), no more than 9 credits of Math 699 can be counted toward the degree. If more research credits are desired, they can be taken under Math 597 (which is repeatable up to 12 credits). No more than a combined total of 21 dissertation and research credits may be applied toward the PhD degree (see Graduate Guide-PhD1).

11 Program of Studies Forms

The student and the student’s advisor design a program of study for each student. Each year the student must complete (or update) an advisor-approved Program of Study form which is to be kept on file in the Mathematics office. A revised form must be filed if there are any changes to the student’s program during the year. This can be done by editing, & initialing and resubmitting the approved form on file.

Please note the following deadlines to submit completed (or updated) Program of Studies forms (submit to the Linda in MA 105):

Program of Studies forms are available at http://cas.umt.edu/math/graduate/current-grad.php.
Please avoid the following common mistakes:

- Program of studies forms submitted without signature of an advisor. Since a plan of studies is to be devised in consultation with an advisor, programs of studies are to be advisor approved. Forms without an advisor’s signature will not be accepted.

- All undergraduate courses cannot be used toward the graduate student’s credit load; only undergraduate courses labeled UG in the catalog may be used. If a graduate student wants to learn an undergraduate subject by taking 100, 200 or 300 level courses in this subject (for example in a foreign language or in computer science), there is no objection to this if the total number of graduate or UG courses is at least that specified by a student’s program.

- Program of studies forms not submitted by the deadline. The Graduate Committee reviews these forms prior to the end of the spring semester for continuing students and the beginning of fall semester for new students so that corrections can be made, if necessary. It is important that the program of studies forms are submitted on time.

12 MA Research Component

Every MA degree program must contain a research project in which the student writes a Master’s Thesis, Professional Paper or does an In-house Project. At the start of the student’s research the student should form an Examining Committee comprised of a minimum of three faculty members. The Examining Committee will then be approved by the Graduate Committee. In the case of a master’s thesis or professional paper the Examining Committee must also be approved by the Graduate School. The size and composition of this committee is specified by Graduate School Policy C6.000, which reads:

**C6.100 — Examining Committee Composition—MA Thesis/Professional Paper**

The examining committee shall be comprised of a minimum of three voting members as follows:

1. A qualified UM faculty member or adjunct from the program or unit granting the
degree who shall serve as chair;

2. A second qualified UM faculty member or adjunct from the program or unit granting the degree, or from a cooperating program or unit in the case of interdisciplinary degree programs;

3. A qualified UM faculty member or adjunct from a program or unit other than the one granting the degree whose primary responsibility is to ensure that the student is held to reasonable academic standards, that the student is treated fairly by all committee members, and that the student’s progress is not unduly delayed by failure of committee members to act in a timely manner.

Note that the above policy requires one member on the committee to be from outside our department; the Graduate School will not approve of the committee if it does not have a member from outside the department.

There are three ways to complete the research requirement for the master’s degree:

(i) Master’s Thesis. The Examining Committee must be approved by the Graduate School and the Graduate Committee; note that the committee must contain a member from outside the Department of Mathematical Sciences.

(ii) Professional Paper for the Library. The Examining Committee must be approved by the Graduate School and the Graduate Committee; note that the committee must contain a member from outside the Department of Mathematical Sciences.

(iii) In-house Project. The Examining Committee requires only Graduate Committee approval; note that the committee need not have a member from outside the Department of Mathematical Sciences.

To form your Examining Committee, first consult with your adviser regarding faculty that may be appropriate to serve based on their interests, qualifications, and availability. Contact each faculty member to determine his or her availability and willingness to serve. Then request approval from Graduate Chair by submitting a Committee Request Form, available on-line. Upon approval by Graduate Committee, the Examining Committee will be recommended to the Graduate School for appointment.

13 PhD Comprehensive Exams and Beyond

13.1 Comprehensive Examination

Following the PhD Preliminary Exams, a doctoral student needs to select a Comprehensive Examination Committee, consisting of the student’s advisor and at least three additional members of the mathematics faculty and a faculty member from a cognate field. To form this committee, contact each faculty member to determine his or her availability and willingness to serve. Then request that the Graduate Chair recommend the committee for appointment to the Graduate School. The Comprehensive Examination Committee’s duty will be to design, administer and assess a written Comprehensive Examination. A syllabus of the topics to be covered on this examination will be prepared by the Comprehensive Examination Committee in a meeting in consultation with the student. The examination emphasizes, but is not restricted
to, the area of specialization of the student. The specific areas and form of the examination are to be determined by the examining committee. The Graduate Committee must approve of the syllabus and form of the examination at least one month prior to the examination date.

A LaTeX template for a PhD Comprehensive Examination proposal is available on-line.

13.2 Advancement to Candidacy

A doctoral student is “advanced to candidacy” when the student has satisfied the Preliminary Examination requirement (see section PhD 3 in the “Guide to Graduate Programs in Mathematical Sciences”) and Comprehensive Examination requirement (see section PhD 5 in the “Guide to Graduate Programs in Mathematical Sciences”).

13.3 Dissertation and Dissertation Proposal

Once an advisor accepts a doctoral student as a dissertation advisee, the student needs to select a Dissertation Committee, consisting of the student’s advisor and four other faculty members. At least one faculty member must be, and two may be, from outside the Mathematics department. To form this committee, contact each faculty member to determine his or her availability and willingness to serve. Then submit a Committee Request Form the Chair of the Graduate Program.

Doctoral students should submit a proposal and research schedule to the committee before the beginning of the student's dissertation research. This proposal is for your use and your committee's guidance and in no sense is a contract.
14 Writing of MA Project/PhD Dissertation

The books by Gillman [5] and Krantz [6] discuss various aspects of mathematical writing. The typesetting system TEX designed by Donald Knuth in the late 1970s, and \LaTeX, a collection of high-level macros built on TEX developed by Leslie Lamport in the early 1980s, have become the standard for typesetting mathematical documents. The following book provides an introduction to \LaTeX that goes well beyond the basics.


A more comprehensive treatment of \LaTeX is contained in the new edition of the *\LaTeX Companion* (which is over 1000 pages):


15 Teaching

15.1 Teaching Assistants

A teaching assistant normally has duties equivalent to teaching 3 to 4 hours per week. First time teaching assistants are required to enroll in the College Teaching Seminar Math 694.

The following book

Steven G. Krantz, *How to Teach Mathematics*, second edition, American Mathematical Society, Providence, 1999,

contains advice on a large number of issues that relate to teaching at the post-secondary level; views on teaching different than those of Krantz are included in more than a dozen appendices.

Bruce Reznick has posted a version of his booklet for teaching assistants (originally published by Random House Birkhauser in 1985) online: http://www.math.uiuc.edu/~reznick/ciu.html

Bruce Reznick (University of Illinois at Urbana-Champaign), *Chalking It Up: Advise to A New TA*, third edition, 1999.

URL: http://www.math.uiuc.edu/~reznick/ciu.html

1. A list of references is given on page 26.
Tom Rishel is maintaining an online handbook for teaching assistants:

Tom Rishel (Cornell University & The Mathematical Association of America), *A Handbook for Mathematics Teaching Assistants*,

URL: http://www.maa.org/programs/tahandbook.html

15.2 PreDoctoral Associates

Advanced PhD Graduate Students who have completed all coursework and are in good standing are eligible for a PreDoctoral Associate position. The position provides advanced graduate students with an opportunity to teach a wider variety of courses and gain more experience for the teaching aspects of their careers.

16 Colloquium talk requirement

According to PhD 1 d) 3 an Option II student must do a current topic project which requires the student to present an expository talk in the Mathematics Colloquium series. The Guide contains the following language about the subject of this colloquium presentation:

The subject of the talk, to be agreed upon by the student and his/her advisor, should be based on reading in the current mathematics literature, or on a study of mathematical literature, or on the student’s experiences in an applied consulting project.

Since the Option I student is to give a Colloquium talk on the student’s dissertation (see PhD 8, which requires an expository talk in a mathematics colloquium in the general area of the dissertation topic, for both options), the above mentioned requirement means that an Option II student is to present an additional Colloquium on a current topic. Note that this colloquium talk is in addition to an colloquium talk on the student’s dissertation as required in PhD 8.
### 17 Example of time line for MA degree

<table>
<thead>
<tr>
<th>Year</th>
<th>Autumn Semester</th>
<th>Spring Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coursework: 2–3 courses</td>
<td>Coursework: 2–3 courses</td>
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<tr>
<td></td>
<td>Teaching</td>
<td>Comp Exam</td>
</tr>
<tr>
<td></td>
<td>Seminar</td>
<td>Colloquium</td>
</tr>
<tr>
<td>Comp passed</td>
<td></td>
<td>Comp passed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(last chance)</td>
</tr>
<tr>
<td>2</td>
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<td>Coursework: 2 courses</td>
</tr>
<tr>
<td></td>
<td>Seminar</td>
<td>Seminar</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td>Research</td>
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</tbody>
</table>

#### 18 Remarks
- Research should be taken under M 597 as well as M 593 and 599.

### 18 PhD Plan

#### 18.1 PhD Plan direct from BA (Additional Option II req in parentheses)

<table>
<thead>
<tr>
<th>Year</th>
<th>Autumn Semester</th>
<th>Spring Semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Coursework: 2–3 courses</td>
<td>Coursework: 2–3 courses</td>
</tr>
<tr>
<td></td>
<td>Teaching</td>
<td>Transfer Courses</td>
</tr>
<tr>
<td></td>
<td>Seminar</td>
<td>Colloquium</td>
</tr>
<tr>
<td></td>
<td>Seminar</td>
<td>Comp Exam</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td>Comp Passed</td>
</tr>
<tr>
<td></td>
<td>Seminar</td>
<td>Adv to Candida-</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Coursework: course(s)</td>
<td>Coursework: course(s)</td>
</tr>
<tr>
<td></td>
<td>Seminar</td>
<td>Seminar</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td>Research</td>
</tr>
<tr>
<td></td>
<td>Seminar</td>
<td>Seminar</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td>Research</td>
</tr>
<tr>
<td></td>
<td>(Teaching Internship)</td>
<td>(Current Topic Project)</td>
</tr>
<tr>
<td>Comp Passed</td>
<td></td>
<td>Comp Passed</td>
</tr>
<tr>
<td>Adv to Candida-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Coursework: course(s)</td>
<td>Coursework: course(s)</td>
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<tr>
<td></td>
<td>Seminar</td>
<td>Seminar</td>
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<tr>
<td></td>
<td>Research</td>
<td>Research</td>
</tr>
<tr>
<td></td>
<td>(Diss Proposal)</td>
<td>(Current Topic)</td>
</tr>
<tr>
<td>4</td>
<td>Seminar</td>
<td>Seminar</td>
</tr>
<tr>
<td></td>
<td>Research</td>
<td>Research</td>
</tr>
<tr>
<td></td>
<td>(Diss Proposal)</td>
<td>(Current Topic)</td>
</tr>
<tr>
<td>5</td>
<td>Research</td>
<td>Research</td>
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<tr>
<td></td>
<td>(Coll Talk Current Topic)</td>
<td>PhD completed</td>
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<tr>
<td></td>
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<td>Dis Defense</td>
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### 18.2 PhD Plan including an MA (Additional Option II req in parentheses)

<table>
<thead>
<tr>
<th>Year</th>
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<th>Spring Semester</th>
</tr>
</thead>
</table>
| Year 1 | Coursework: 2–3 courses  
Teaching  
Seminar | Comp Exam  
Coursework: 2–3 courses  
Colloquium |
|     | Comp passed  
Coursework: 2 courses  
Seminar  
Research | Coursework: 2 courses  
Seminar  
Research |
| Year 2 | Coursework: 2–3 courses  
Teaching  
Seminar | Transfer Courses  
Coursework: 2–3 courses  
Colloquium |
|     | Prelim 1  
Coursework: 2 courses  
Seminar | Prelim 2  
Passed  
Coursework: 2 courses  
(Prep Teach Internship) |
|     | Comp Exam  
Prop |
| Year 3 | Coursework: course(s)  
Seminar  
Research  
(Teaching Internship) | Comp Passed  
Adv. to Candidacy  
Coursework: course(s)  
Seminar  
Research  
(Current Topic Project) |
|     | Coll Talk  
Current Top.  
(Diss Proposal) |
| Year 4 | Coursework: course(s)  
Seminar  
Research | Coll Talk Diss  
(Diss Defense) |

**Remarks**

- The number of courses per semester will depend on the student’s preparation prior to entering the program. It is strongly recommended that doctoral students submit a request for transfer of graduate coursework completed prior to admission into our program or before the start of their second semester in the program. Obviously, the amount of coursework in subsequent semesters will be dependent upon approval of transferred coursework, so to plan for timely completion of the course requirements it is important that
transfer requests be made as early as possible (which, according to Graduate School policy D2.101 is after one semester in the program).

- The indicated times for passing the two preliminary exams in the above chart are the latest these exams can be passed according to our Guide.

- Doctoral students in option II need to plan a Teaching Internship one semester prior to doing this Teaching Internship. The appropriate course number for the Teaching Internship and/or its preparation is M 690. Of course, this Teaching Internship can be done any semester; in the chart we have put it between completion of the Preliminary and Comprehensive Examination requirements.

- The chart shows the study of the current topic project (appropriate course numbers are M 593 and M 597, since this current topic project is separate from the dissertation research) in the student’s 6th semester of the program. The colloquium talk based on this current topic project is best presented prior to the end of the 7th semester in the program.

Depending on the number of completed credits, research should be taken under M 597 as well as M 699. The appropriate course number for dissertation research is M 699. However, since M 699 is repeatable for up to 9 credits, no more than 9 credits of M 699 can be counted toward the degree. If more research credits are desired, then they can be taken under M 597 (which is repeatable up to 12 credits).

19 Graduation Form & Graduation Checklist

The graduation application and graduation checklist are available on-line. (The graduation application is on the Graduate School website & the graduation checklist is on the department’s website.) Please submit both to the graduate director for approval. Upon approval, the graduate application form will be submitted to the graduate school. The application and checklist are due at the end of the semester prior to the semester of graduation. For this academic year the following deadlines apply:

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 16</td>
<td>Spring Graduation Applications for MA and PhD due. All requirements must be completed by June 19. Please submit paperwork to graduate director two weeks prior to this deadline.</td>
</tr>
<tr>
<td>May 14</td>
<td>Last day of Spring Semester and award date for Spring degrees</td>
</tr>
<tr>
<td>May 8,</td>
<td>Summer Graduation Applications for MA and PhD due All requirements must be completed by August 31.</td>
</tr>
<tr>
<td>July 31</td>
<td>Last day of Summer Semester and award date for Summer degrees</td>
</tr>
<tr>
<td>September 15</td>
<td>Fall Graduation Applications for MA and PhD due</td>
</tr>
</tbody>
</table>

20 Resources

Following are several useful resources for graduate students in the mathematical sciences. Krantz’s Survival Guide contains advice from preparing and applying to graduate school to the life of an assistant professor.
Most of the cartoons used in this “Supplement” come from Jorge Cham’s website *Piled Higher and Deeper* [11], which contains hundreds of cartoons depicting graduate life (or lack thereof). The cartoons on pages 10, 16, 20 and 24 (top two) come from John dePillis’ book *777 Mathematical Conversation Starters* [12], which in addition to illustrations by the author contains numerous quotations from mathematicians, as well as mathematical poems and songs.

**References**


