Title of degree: Bachelor of Science

Intellectual background: Mathematics has been studied systematically for more than 2500 years and continues to be an area of active research. The last decade has seen progress on problems that have been open for more than a century, e.g., Perelman’s proof of Poincaré’s conjectural characterization of three-dimensional spheres, Bhargava’s work extending Gauss’ 200-year-old composition rules for quadratic forms, and many others. Many current advances in science and technology rest on mathematical foundations.

Context and rationale: Our BA and minor programs work well for students seeking broad mathematical training that is applicable to a wide range of different fields. They do not recognize the needs of our best undergraduates who plan graduate study in mathematics. While we offer the courses these students need, they have never been organized into a coherent program. Indeed, we fail to communicate clearly the key courses students need to be competitive for top graduate programs.

In Fall 2012, our department underwent an external review and one of the headline recommendations was:

the committee feels that the Department and University should explore the establishment of a Bachelor of Science in Mathematics

This issue has been percolating in our department for a long time, ever since BS degrees were introduced in the Wiess School of Natural Sciences more than a decade ago. The external review recommendation brought this to a head, leading to active discussions in our Undergraduate Committee throughout Spring 2013.

Programs at peer institutions: A number of schools offer only the BA degree in Mathematics; some schools only offer BS degrees, e.g., CalTech, MIT, Stanford, and UCLA. Several institutions have both BA and BS programs in Mathematics. In the cases we know, the BA requirements are a subset of the BS requirements. For example,
at Yale the BS program requires two advanced term courses in the physical sciences beyond the BA. The University of Chicago requires BS students to take one additional quarter course in Algebra.

Rice’s BA in Mathematics requires calculus (MATH 101, 102, 211, and 212 or the 221/222 sequence) and 24 credit hours at the 300-level or higher but no specific upper-level courses. The proposed BS degree requires more courses and specific topics relevant for further study in mathematics.

**Unique contribution of this program:** The BS degree program codifies our faculty’s view of what courses are most important for graduate study in mathematics. It also recognizes the efforts of our most ambitious students.

**Departmental endorsement:** This proposal originated in the MATH department Undergraduate Committee, whose membership reflects a wide cross-section of our faculty: Tim Cochran (chair), Danijela Damjanović, Zhiyong Gao, Frank Jones, Andy Putman, Stephen Semmes, and Brendan Hassett (*ex officio* as department chair). All members actively suggested possible required courses; the committee also consulted with current mathematics majors. The committee’s proposal was circulated among the regular faculty, who met April 22, 2013 and unanimously approved it.

**Proposed language for the General Announcements:** To be inserted between ‘Degree Requirements for BA in Mathematics’ and ‘Course requirements for a Minor in Mathematics’:

**Degree requirements for BS in Mathematics**

These requirements are in addition to general university graduation requirements. The chair of the undergraduate committee of the MATH department may modify requirements to meet the needs of students with advanced backgrounds. Required courses include:

- Single variable calculus: MATH 101 and 102;
- Differential equations: MATH 211, 381, or 423;
- Multivariable calculus: MATH 212, or both 221 and 222;
- Linear algebra: MATH 221, 354, or 355;
- Real analysis: two classes taken from MATH 321, 322, or 425;
- Algebra: MATH 356 and 463;
• Geometry and manifolds: MATH 370, 401, or 402;
• Complex analysis: MATH 382 or 427;
• Topology: MATH 443, 444, or 445;

A total of at least 33 credit hours in MATH (e.g., 11 three-hour courses) at the 300 level or above is required. Students may choose electives to reach this number. At most three credit hours for any given course number may be used for this degree.

Comments on the requirements: MATH 221 presents calculus in an arbitrary number of variables, which necessitates the parallel development of both linear algebra and multivariable calculus concepts. This is why it satisfies both requirements. However, while MATH 221 may satisfy the linear algebra requirement, MATH 354 and 355 do not satisfy the multivariable calculus requirement. Moreover, MATH 221-222 should be taken together. Taking MATH 222 without MATH 221 is very difficult, even after MATH 355/354; taking MATH 221 and then MATH 212 is possible but advisable only for students that dislike the abstraction of MATH 221. Students completing MATH 221-222 in their first year are usually better served by an upper-level differential equations class (MATH 381 or 423) rather than MATH 211.

Faculty participation: The MATH department has 15 regular faculty, including one Assistant Professor, four Associate Professors, and ten Professors. We also have eight Instructor lines, which typically translate into 10 or more individuals. All faculty teach undergraduate courses applicable to this degree. The required courses are routinely offered already; with the exception of MATH 370, every course has been offered annually since 2007. (MATH 370 was created in Spring 2011 and offered again in Spring 2013.) We do not limit enrollments of courses taught by our faculty, as they are frequently required for majors across the university. The BS program will have a minimal impact on our course staffing requirements.

Compatibility with General Announcements: This degree is consistent with existing university requirements. The number of required courses is comparable to BS programs in other science departments. The requirements we propose will not automatically be satisfied in the course of any existing major or minor.

Accreditation statement: The learning outcomes of the mathematics BS program include:

• deep understanding of calculus in one and several variables;
• working knowledge of differential equations;
• theoretical understanding of and solutions techniques for linear equations;
• broad knowledge of real analysis and algebraic structures at the undergraduate level;
• familiarity with key methods of modern geometry, functions in a complex variable, and topology;
• the ability to read, assess, formulate, develop, and write formal mathematical arguments;
• an overall level of mathematical sophistication necessary to follow graduate-level courses.

The proposed curriculum closely reflects these objectives—each of the required courses supports one or more of the first five subject-matter outcomes. A number of courses (MATH 221-222, 321, 354) focus on proof-writing; all subsequent courses reinforce this outcome. The last outcome will be guaranteed by the overall number and level of the required courses.

The BS in mathematics will be evaluated as part of our annual accreditation review. Each year we typically evaluate a required course for each of our programs, to determine whether it continues to meet our curricular and programmatic objectives.

Notes on implementation: The Mathematics Department attracts some students with extraordinary backgrounds. We occasionally have incoming freshmen with knowledge in a specific area comparable to beginning graduate students. It is counterproductive to compel these students to retake material they have already mastered. We summarize cases where the chair of the undergraduate committee may modify requirements to take individual circumstances into account.

(1) A student may seek to substitute a more advanced course in the same area for a required course. For example, the department might accept MATH 428 for the complex analysis requirement.

(2) If a student has taken classes at another institution that substantially cover the material in a required course, this course might be waived. This might be appropriate even if the class did not qualify for Rice Equivalent Credit. For example, if a student took a course in the partial differential equations of mathematical physics at another school, the department might waive the differential equations requirement.

(3) If a student participates in an REU (Research Experience for Undergraduates) or similar program that substantially covers the content of a required course, the department may waive
that course. For example, if a student did a summer research project in conformal mappings, the department might waive the complex analysis requirement.

(4) If a student acquires knowledge covered by a required course and successfully completes a more advanced course at Rice using that knowledge, the department may waive the lower-level course. For example, the department may waive MATH 101 for students that successfully complete MATH 211.

In cases (2)-(4), the waiver will not reduce the 33 hours required at the 300-level or above.
Sample Degree Plans for the BS in MATH

Rice Department of Mathematics

January 2014

Assuming no AP Credit

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<th>3rd year</th>
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<td>Fall</td>
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<td>MATH 211</td>
<td>MATH 321</td>
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<td>MATH 355</td>
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<td>Spring</td>
<td>MATH 102</td>
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This is a minimal plan in that all the listed courses are needed to meet degree requirements.

Assuming AP BC Calculus Credit for MATH 101/102

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<tr>
<td>Fall</td>
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<td>MATH 427</td>
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This plan includes electives beyond those needed to meet the degree requirements. This might be appropriate for a student considering graduate study in pure mathematics.