2018-19 AY Assessment Report M.A. in Mathematics.

Department and Degree: Department of Mathematics. Masters of Arts in Mathematics Assessment Coordinator for the Graduate Program: Oscar Vega.

1. Learning outcomes assessed this year

Direct Assessment.

We assessed four courses this AY: MATH 223, MATH 232, MATH 251, and MATH 263. MATH 251 is one of the two core courses in our program (the other one was assessed last year), MATH 223 is a recently created course.

(1) Embedding questions in exams. The goals and SLOs assessed this year by using embedding of questions were:

Goal A. Provide students with advanced knowledge in the core areas of mathematics at the graduate level.

A1. Students will understand, describe, and illustrate the structural relationships among fundamental concepts in abstract algebra and real analysis (and geometry for students in the Teaching Option), such as function/transformation, derivative, integral, matrix, number/function set, algebraic structure (group, field, etc.).

Goal B. Continue development of students’ ability to read, understand, and write rigorous mathematical proofs.

B1. Students will read, understand, and be able to reconstruct rigorous proofs of classical

theorems in algebra and analysis. B2. Students will write advanced proofs in algebra and analysis.

Goal C. Provide students with opportunities to apply mathematical knowledge to solve theoretical and practical problems.

C1. Students will utilize advanced problem-solving skills.

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C2. Students will enhance computational and visualization skills by utilizing mathematical

software.

Goal D. Continue development of students’ communication skills, both written and oral for purposes of conveying mathematical information.

D1. Students will be able to explain their solutions and proofs both orally and in writing.

(2) Oral presentations. The goal and SLO assessed this year by using oral presentations was:

Goal D. Continue development of students’ communication skills, both written and oral for purposes of conveying mathematical information.

D1. Students will be able to explain their solutions and proofs both orally and in writing.

(3) Course projects. The goal and SLO assessed this year by looking at course projects was:

Goal C. Provide students with opportunities to apply mathematical knowledge to solve theoretical and practical problems.

C1. Students will utilize advanced problem-solving skills.

Goal D. Continue development of students’ communication skills, both written and oral for purposes of conveying mathematical information.

D2. Students will be able to use technology in written reports and oral presentations.

(4) Thesis and Project rubrics. We use a rubric to measure the quality of the content (the math), the writing, and presen- tation (defense).

Indirect Assessment.

We looked at the exit surveys and exit interviews the graduate committee collected from the 2018-19 graduating class. Also, we looked at the one survey we obtained from the 2017-18 graduating class, as it was not used last year (too little data).

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2. Assignments and/or surveys used to assess the outcomes and criteria/rubrics

used for evaluation.

We list here only information for direct measures, as we do not have benchmarks for indi- rect measures and the project/thesis analysis. Rubrics are provided at the end of this report.

(1) Embedding questions in exams.

This year, we opted to use both final exams and midterms for the embedding of questions. Also, given that some faculty (e.g. MATH 251 in this assessment report) write exams that allow students to not have to approach every question in the test, we decided that, when possible, we would embed more than one question per exam. In this case, we will take the best of the two scores for the same SLO a student obtained.

A1. Two embedded questions on the MATH 251 final exam in Spring of 2019.

The instructor considers that every student in the class should score at least 8/10 (80%) in at least one of these two questions. One of them is fairly standard for a course of this type. B1. Two embedded questions on the MATH 263 final exam in Fall of 2018.

These questions are typical (homework-like) exercises. Thus the instructor considers that these are easy and expects that every student will score at least 8/10 (80%) in at least one of these problems. One embedded question on the MATH 263 second midterm in Fall of 2018. Given that this question is fairly typical in a course like this one, the instructor expects that most students will be successful getting a complete solution. However, there are a few details that students will have to be careful about, thus the instructor considers that all students should score at least 14/20 (70%) in this question. Two embedded questions on the MATH 251 final exam in Spring of 2019. The instructor considers that every student in the class should score at least 7/10 (70%) in at least one of these two questions. B2. Two embedded questions on the MATH 263 final exam in Fall of 2018.

One of these questions describes an object students are familiar with but in a con- voluted way. The other problem deals with a construction students are also familiar with. However, there are many details students will need to be very careful with when writing their solutions. Still, the instructor considers that everybody should score at least 8/10 (80%) in at least one of these questions. One embedded question on the MATH 263 second midterm in Fall of 2018. This is a problem that had been discussed in class (it is a famous theorem). Hence, the instructor expects that everybody gets at least 17/20 (85%). One embedded question on the MATH 251 final exam in Spring of 2019. The instructor says that this was one of the hardest questions in the test. Hence,

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although he would like to have all students scoring at least 7/10 (70%), he would consider acceptable that all of them scored at least 6/10 (60%). C1. Two embedded questions on the MATH 251 final exam in Spring of 2019.

These problems were not really difficult but were long and time-consuming. Students had to consider several cases. However, this was a take-home exam, and this why the instructor considers that every student in the class should score at least 7/10 (70%) in at least one of these questions. Two embedded questions on the MATH 223 final exam in Spring of 2019. The instructor thinks that a score of 9/12 (75%) in the first question would be satisfactory. However, he expects a 10/12 (83%) average score. For question two, the instructor thinks that a score of 7/10 (70%) in this question would be satisfactory. However, he expects an 8/10 (80%) average score. C2. One embedded question on the MATH 232 second midterm in Fall of 2018.

The instructor thinks that an average of 14/20 (70%) would be acceptable. D1. One embedded question on the MATH 223 final exam in Spring of 2019.

The instructor thinks that a score of 7/10 (70%) in this question would be satisfactory. However, he expects a 7.5/10 (75%) average score.

(2) Oral presentations.

D1. One oral presentation on the second midterm of MATH 263 in Fall of 2018. Presentations were done by students solving on the board homework-type problems. Since these presentations were a part of Midterm 2, the problems were difficult. Be- cause of this, the instructor expected that students would score around 30/35 (86%) points. Students were not given a second chance to give their presentations. One oral presentation on the MATH 251 second midterm in Spring of 2019. The maximum score for presentations was 35 points. In the Fall, the instructor set the benchmark at 30/35 (85%). That very same benchmark will be used for this class as well, but given that students were going to receive feedback and then be allowed to repeat their presentation, the instructor considered that everybody should score at least 32/35 (91%). Final Project for MATH 232 in Fall of 2018. The part of the final project relevant to this SLO was evaluated through an oral pre- sentation (worth 25 points of the 80 possible points on the final project). A score of 17.5/25 (70%) would be acceptable, but the instructor anticipated that the score on the oral presentation would be at least 18/25 (72%).

For oral presentations we used a scoresheet this time. We will develop a rubric for this type of assessment, during the 2019-20 AY, that will be suggested as a template to instructors. This scoresheet may be found at the end of this document.

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(3) Course projects.

C1. Final Project for MATH 232 in Fall of 2018.

The part of the final project relevant to this SLO comprised 30 of the 80 possible points for the grade on the project. A score of 21/30 (70%) would be satisfactory, but the instructor expected scores of at least 24/30 (80%). D2. Final Project for MATH 232 in Fall of 2018.

The part of the final project relevant to this SLO was evaluated through a written paper (worth 25 points), which comprised 25 of the 80 possible points on the final project. A score of 17.5/25 (70%) would be acceptable, but the instructor anticipated that the score on the papers would be at least 20/25 (80%).

3. Discoveries from data gathered

MATH 232: We assessed one section of this course in the Fall of 2018. Six students took the midterm and submitted the final project. The final project was out of 80 points. The midterm was out of 100 points. SLO C1. Final Project for MATH 232. The benchmark is: a score of 21/30 would be satisfactory, but the instructor expected scores of at least 24/30. All but one student (i.e. 83% of them) achieved the acceptable score (with scores of 23, 23, 25, 29, and 29); the only unacceptable score was 18/30. The low score may be due in part to the fact that it was extremely difficult to follow the student’s work well, along with the typos that appeared in the project paper. Overall, the instructor was pleased with the results, since half of the students met expectations. SLO C2. One embedded question on the MATH 232 second midterm. The benchmark is: an average of 14/20 would be acceptable. The average score was only 12.33/20, with only two students achieving an excellent (18) or more than acceptable (15) score (i.e. 33% of them). The remaining scores were 12, 11, 9, and 9. Most of the students failed to apply the procedures for discrete systems, instead simply applying the more familiar tools for continuous systems. This was surprising since the class notes, as well as solutions for the relevant homework assignment, had been posted before the exam was taken. In the future, more time should be taken exploring discrete systems and emphasizing the differences in approach between discrete systems and continuous systems. SLO D1. Final Project for MATH 232. The benchmark is: a score of 17.5/25 would be acceptable, but the instructor anticipated that the score on the oral presentation would be at least 18/25. The students performed as follows: 25, 25, 25, 24, 21.5, and 17.5. The instructor was ex- tremely pleased by the presentations, since 100% of them achieved the minimum acceptable score, and most of the students performed well above expectations.

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SLO D2. Final Project for MATH 232. The part of the final project relevant to this SLO was evaluated through a written paper (worth 25 points), which comprised 25 of the 80 possible points on the final project. A score of 17.5/25 would be acceptable, but the instructor anticipated that the score on the papers would be at least 20/25. The students performed as follows: 24, 24, 22, 19, 18, and 11.5. All but one student (i.e. 83% of them) at least meeting the minimum acceptable score and three students (i.e. 50% of them) exceeding the instructor’s expectations. Summary: Only SLO C2 seemed to be a problem; all the other SLOs were satisfied by most of the students. Changes that may be used to improve in SLO C2 are described above, at the end of the item corresponding to that SLO.

MATH 263: We assessed one section of this course in the Fall of 2018. Six students took the midterm and the final exam. The final exam was take-home and consisted of 12 questions, ten points each, with a maximum score of 100 points (hence, there were 20 points of ‘extra credit’). Because of the exam format, we assessed two questions per SLO whenever possible. The midterm had an oral component (35 points) and an in-class test counting for 80 points (hence, there were 15 points of ‘extra credit’). SLO B1. One embedded question on the MATH 263 second midterm. The benchmark is: every student scores at least 14/20. Only one student (i.e. 16% of them) was able to perform at an expected level (perfect score). The other five scores were 10,10,10,10, and 12. The average being 12/20 is not good. The low scores were due mostly to them not being able to come up with a function that could be used to do part (b) although they were able to do part (a). Hence, 10/20. SLO B1. Two embedded questions on the MATH 263 final exam. The benchmark is: every student scores at least 8/10 in at least one of these problems. Every student (i.e. 100% of them) scored at least a 9 in at least one of these problems. This is above expected, but the questions were fairly standard. SLO B2. One embedded question on the MATH 263 second midterm. The benchmark is: every student gets at least 17/20. Four students (i.e. 66% of them) had a perfect score in this question, the other two scores were 5, 15. Hence, the average was 16.7, which is right below expectations. SLO B2. Two embedded questions on the MATH 263 final exam. The benchmark is: every student scores at least 8/10 in at least one of these questions. Five students (i.e. 83% of them) scored at least 8/10 in at least one of the questions. The other (best) score was 5/10. This yields an excellent 9/10 average. The high scores are due to students being able to see through the complicated way to describe the object in one of the questions and then proceed using standard techniques, which simplified the problem greatly. SLO D1. One oral presentation on the second midterm of MATH 263. The benchmark is: students should score at least 30/35.

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The scores obtained were 25, 27, 29, 30, 32, and 34, which average to 29.5. This is below that what was expected, as only 50% of the students performed at the benchmark level. The instructor says that students got caught in the difficulty of the problem and did not take enough care of how to present their work. He says that after this he decided that in the future he will give students some feedback after their presentation and then ask them to present for a second time. This was implemented in MATH 251 in the following semester (see below). The results in MATH 251 show a clear improvement in the quality of the student presentations after making the small adjustment mentioned above. Summary: Both the oral presentation part and one of the two assessment of SLO B1 are reasons for concern. The oral presentations part was addressed in Spring 2019 in MATH 251 with great results. Now, if we compare the results of the two assessments of SLO B1 we see that type of question given to the students made a big difference. This is not too surprising, as harder questions will get worse performances from students than easy questions.

MATH 223: Two of the two students enrolled in the course took the final. The final exam consisted of a 70% take-home problem-solving part and a 30% theoretical (oral) part with an optional opportunity to earn 5 extra credit points by answering additional random questions. C1. Two embedded questions on the MATH 223 final exam in Spring of 2019. The benchmark is as follows. First question: a score of 9/12 (75%) would be satisfactory but a 10/12 (83%) is expected. Second question: a score of 7/10 (70%) would be satisfactory and an 8/10 (80%) is expected. The students’ scores were as follows: (Q1) 9/12 and 11/12 (for an average of 10/12) and (Q2) 7/10 and 10/10 (for an average of 8.5/10). Hence, 100% of the students performed at a satisfactory level and 50% at the expected level. D1. One embedded question on the MATH 223 final exam in Spring of 2019. The benchmark is: a 7/10 (70%) would be satisfactory, and a 7.5/10 (75%) would be expected. The students’ scores were: 8/10 and 7/10, for an average of 7.5/10. It follows that 100% of the students performed at a satisfactory level and 50% at the expected level. Regarding the extra credit part, the instructor has no expectations for this part. Both students scored a 3/5 in this part.

MATH 251: We assessed one section of this course in the Spring of 2019. Six students took the midterm and the final exam but one of the students scored zero in every question assessed in the final (for personal issues the student was going through at the time, they submitted solutions for only five questions in the exam). The final exam was take-home and consisted of 12 questions, ten points each, with a maximum score of 100 points (hence 20 points of ‘extra credit’). Because of the exam format, we assessed two questions per SLO

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whenever possible. The only part of the midterm that was assessed was the oral component of it, which counted for 35 points (out of 100 total for the midterm). SLO A1. Two embedded questions on the MATH 251 final exam. The benchmark is: every student scores at least 8/10 in at least one of the questions. All but one student (i.e. 83% of them) scored above 8 in one of these questions (the easier one). The other student scored a zero in both questions. The average obtained this way is 8.3, which is considered to be good by the instructor (a solid B). Eliminating the student who got a zero, 100% of the students performed at the expected level. SLO B1. Two embedded questions on the MATH 251 final exam. The benchmark is: every student scores at least 7/10 in at least one of the questions. Three students (i.e. 50% of them) scored at least 7/10 in at least one of these questions. The best scores for the other three students were 0, 5, and 6. In this way, we get the average 5.8, which the instructor considers low, and definitely below his expectations (7/10). Eliminating the student who got a zero, the average is 7, which is what was expected. SLO B2. One embedded question on the MATH 251 final exam. The instructor considers that a 6/10 is acceptable. Three students (i.e. 50% of them) scored at least 6/10. The other scores were 0, 0, 2. The instructor feels that the lowest three scores are caused by the difficulty of the question and that students could ‘opt out’ of this question. The average was a 4.3, which is below acceptable. In fact, even eliminating the student who got a zero, the average is 5.2, which is still unacceptable. As an afterthought, the instructor knew this would be the hardest question in the test, thus the low benchmark. However, he was taken aback by the low performance. He will include questions that are similar to this one in assignments the next time he teaches this class. SLO C1. Two embedded questions on the MATH 251 final exam. The benchmark is: every student scores at least 7/10 in at least one of the questions. Only two students (i.e. 33% of them) scored at least 7/10 in these questions. The other (best) scores were 0, 5, 5, and 6. This yields an average of 5.5 and of 6.6 if the student who got a zero is eliminated. In either case, students performed below expectations. SLO D1. One oral presentation on the MATH 251 second midterm. The bench- mark is: students score at least 32/35. Students usually scored high in the presentations: 24, 31, 31, 32, 32, 35. Hence, all but one of the students (i.e. 83% of them) scored at, or over, the benchmark. Now, regarding the increased expectations, due to the change in the way the presentations were going to be handled, only 50% of the students scored 32/35 or more, two others scored fairly close, and there was an outlier (who did not want to come back for a second presentation after feedback was given). Summary: In general, the benchmarks were modestly reached (with a better average performance once the student who got only zeros is eliminated), except for SLO B2. Con- sidering that the highest level of abstraction is measured by this SLO, the instructor thinks

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that the next time he teaches this class, he will make students more aware of the many possible variations of types of questions that can be written using the topics covered in this course. Also, giving students a chance to ‘rehearse’ their oral presentations proved to be a game-changer (see, above, the comments on the assessment of the oral presentations of MATH 263 in this report).

Exit surveys and interviews: Not much can be extrapolated from only a handful of students graduating every year. In fact, in the 2017-18AY, only two students graduated from our program and only one responded to the Exit Survey. Hence, in this year’s report, we have merged the last two graduating classes to create a higher volume of responses. Two students graduated in the 2017-18AY, six did in the 2018-19AY. From the interviews, it is clear that students have realized that in a small program like ours, with not many courses offered per semester, taking Independent Studies is an effective way to get to learn material that otherwise would not be covered in regular classes (3/8 mentioned that). Also, 3/8 students (33.5% of them) mentioned, in the interviews, a lack of Discrete Mathematics, Applied Mathematics (for people wanting to work in industry) and Geometry courses (see also a related comment in the analysis of the surveys below). From the surveys, it is clear (6 out of 8 students, i.e. 75% of them, mentioned at least one of the following) that our two weakest points are that: (i) we do not provide a wide variety, and/or number, of courses, (ii) we do not provide enough information/guidance to our students that would help them figure out what is going to be out there when they finish their Master’s degree. That is, career opportunities are not clear for many of our students (those who did not have clear that they wanted to pursue a Ph.D. afterwards or were clear about wanted to go into teaching).

Project/Thesis assessment: The six Projects/Theses delivered this semester were assessed using the rubric found at the end of this document. Each one of them was assessed by each of the three members of the corresponding Project/Thesis committee. We use the average of these scores in the table below: STUDENT 1: 73%. Lowest score given by advisor. Thesis (MATH 299) grade: B. STUDENT 2: 81%. Highest score given by advisor. Project (MATH 298) grade: A. STUDENT 3: 86%. Highest score given by advisor. Project (MATH 298) grade: A. STUDENT 4: 87%. Highest score given by advisor. Project (MATH 298) grade: A. STUDENT 5: 89%. Highest score given by advisor. Thesis (MATH 299) grade: A. STUDENT 6: 93%. Lowest score given by advisor. Thesis (MATH 299) grade: A.

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Notice that the grades and the rubric scores are not aligned in a typical 60-70-80-90 grading scale. We will look at this phenomenon in the future to either attempt to align grades with such scale, or to create another that may represent better the way we asses our Projects/Theses.

4. Changes made as a result of findings

ORAL PRESENTATIONS: More a suggestion than a recommendation. Our students have little to no experience presenting their work on the board, mostly if it is material they are learning. The experience in MATH 263 and MATH 251, in which the same instructor in two consecutive semesters had oral presentations as a part of an exam but changed the rules in the second semester, indicate that it is not a bad idea to give students some feedback after their presentation and then ask them to present for a second time. Not only the quality of the presentations was better (by scores) but also students seemed more relaxed and confident when having some practice in advance.

FAMILIARIZE STUDENTS WITH PROBLEMS IN FUTURE EXAMS/PROJECTS. More a comment than a recommendation. This occurred in a couple of classes this AY (two different instructors). The Instructors felt they could have done a better job familiarizing students with certain types of problems, or techniques.

CREATE MATERIALS THAT WILL BE USED TO DIRECT STUDENTS TO CAREER PATHS. The Graduate Committee should develop materials (flyer, posters, lists, presentations, etc) that address the lack of guidance our students feel regarding their future (in terms of jobs). There are two common possible career paths for our students: Teaching at some level and entering a Ph.D. program, but not all our students feel that these paths are for them.

MORE VARIETY OF COURSES, HOPEFULLY MORE COURSES. Study how we could offer a wider variety of courses given the possibility of courses getting cancelled if we have too many classes running. One possibility is to grow the program (in number of students), another is to get undergraduate students to take graduate classes (a 4+1 program is a possibility).

5. Assessment activities to be conducted in the 2019-20 academic year.

(a) Assessment of the SLOs covered by MATH 201, MATH 252, MATH 271, AND MATH 272. This will be done, preferably, by embedding questions in exams, but for courses that are more project-based, we will find a way to assess the corresponding SLOs after consulting and planning with the corresponding instructors.

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(b) We will survey our graduating students to learn about their thoughts and feelings about our program. We will combine their responses with the little data we were able to gather this year. (c) We will assess all projects and thesis delivered this academic year using the rubric at

the end of this document. (d) We will finish the re-write of our current SOAP to match our migration from an MA

to an MS (effective in Fall 2019). (e) We will create rubric ‘templates’ for oral presentations. (f) We will create a repository that will consist of questions that have been used as embedded questions in the past. The idea is that instructors have a source of material they may want to consult at the time they write their own embedded questions.

6. Progress made on items from our last program review action plan

A new SOAP is half-done at this point, to be used in our recently installed Master of Science.

During the 2016-17 AY, we had a site visit to review our programs. The visit occurred on Sept. 28th and 29th, 2016. The review panel consisted of Prof. Kim Morin, Theatre Arts, CSU Fresno, Dr. Saeed Attar, Professor of Chemistry, Director of Honors College, CSU Fresno, and Dr. Ivona Grzegorczyk, Professor and Chair, Department of Mathematics, California State University, Channel Islands. The panel delivered several recommendations that were already discussed in last year’s as- sessment report. Next we report on the items for which we reported no progress last year, and that are relevant to our Master’s program.

A. Curriculum Improvements and Vision for the Future.

Recommendation 4. Faculty should discuss a long-term vision for the department. Last year’s response. We are in the process of changing the degree designation of our pro- gram from an M.A. to an M.S. This change will consist in a re-organization of our courses, creation of new ones and phasing out of others. We believe our new program will be more competitive, modern, and will give our student a high-standards education.

This year’s response. The MS was accepted by the Chancellor’s Office and it has been im- plemented effective fall 2019. One of the main changes in the program is that it does not have any options anymore, and that courses have been organized so there are ‘paths’ that students with various career objectives can follow to achieve their objectives. During this year, we will discuss the creation of a 4+1 program to be able to recruit talented Fresno State students who may want to get a BS and an MS in five years.

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B. Supporting Faculty Research and Workload Issues.

Recommendation (Administration and the Department). Identify sources for long term funding so the program can offer release time or summer stipends to faculty engaging in research and grant-writing activities. Last year’s response. No progress.

This year’s response. No progress.

C. Departmental Budget.

Recommendation. Identify College and University funds to be included in the departmental funding base for faculty scholarly activities and curriculum coordination. Last year’s response. No progress.

This year’s response. No progress.

D. Improving technology use in mathematics courses.

Recommendation. Rethink delivery of the calculus, statistics, and upper division courses to include updated use of technology and current mathematical software. Note: Although this recommendation is specific to undergraduate courses, we have also considered it for graduate courses. Last Year’s Response. The graduate committee wrote a new policy on the usage of tech- nology in graduate courses; our next step is to incorporate these ideas in our new M.S. program and our new SOAP.

This year’s response. We have incorporated the ideas in the policy created last year to our new Goals and SLOs.

E. Supporting Undergraduate and Graduate Student Research.

Recommendation 1. Rethink the ways to involve undergraduate and graduate students into original research rewarding supervising faculty with adequate work load. Last year’s response. The undergraduate research committee has changed its name, and charge, to the student research committee with the idea of also support graduate student research. No progress on the ‘reward’ end, though.

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This year’s response. Students have been heavily advised to pursue theses instead of projects when possible; these would be research theses. The effect of this advising may be felt al- ready, as of all the students graduating in the 2019-20 AY, all but one will work on a thesis. Also, during the 2018-19 AY students were encouraged to present their work at venues beyond Fresno State (CCRS usually features graduate students). Four students obtained funding for travel to go to a conference and present their work. They did well.

Recommendation 2. Create funding for the department to support small courses for faculty student research projects. Last year’s response. No progress.

This year’s response. No progress.

Recommendation 3. Explore the possibility to offer research courses, where full course load is given to faculty for working with small groups of students. Last year’s response. No progress.

This year’s response. No progress.

F. Facilities.

Recommendation (Administration) 1. Try to locate all faculty and graduate student offices in closer proximity to the department. Last year’s response. No progress.

This year’s response. No progress.

Recommendation (Administration) 2. Provide additional space that is equipped appropri- ately for best practices in teaching mathematics that will facilitate faculty/student collab- oration and research activities. Last year’s response. No progress.

This year’s response. No progress.

Recommendation (Administration) 3. Investigate the use of laptops to meet the computing needs of the faculty and students. Last year’s response. No progress.

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This year’s response. No progress.

G. Involving Lecturers in Departmental Activities.

Recommendation 1. Include lecturers in programmatic issues relevant to the courses they teach (especially in committees on instruction and curriculum related to their teaching as- signments). Last year’s response. Travis Kelm was an important part on the development of the re- design of MATH 260. He not only contributed in the selection of topics but also taught the class covering some of the new topics and typing material that was (and will be) used to create a set of lecture notes for this class. Travis also worked on the redesign of MATH 202, which is not currently being offered but that we plan to resuscitate in the near future. Other instructors worked on the re-design of undergraduate-level courses, see the assess- ment report for our B.A. for more details.

This year’s response. No progress.

Recommendation 2. Allocate an additional appropriate space for the program designated to faculty-student collaborations and projects. Last year’s response. No progress.

This year’s response. No progress.

H. Assessment and Student Learning Outcomes

Recommendation. The Student Learning Outcomes should include familiarity with current technology accepted by the mathematical community. Last year’s response. No progress. Any advances on this regard have been made by indi- viduals; our department does not have a plan for this contingency.

This year’s response. It was mentioned before that our new SLOs include technology aware- ness for certain courses. Also, most students will typeset their thesis/project using LATEX, which is a software specially created to typeset mathematics, and would use drawing/geometry programs (such as GeoGebra) to create figures.

The rubrics for all our assessment activities may be found in the following pages.

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Applied Operator Theory (MATH 223) Marat Markin, Ph.D. Spring 2019 1

MATH 223 Final Exam Assessment Rubric

1. SLO C1. Students will utilize advanced problem-solving skills.

Problems 2, 6 (Problem-Solving Part).

2. SLO D1. Students will be able to explain their solutions and proofs both orally and in

writing.

Problem 3 (Theoretical Part).

1. Problem 2 (Problem-Solving Part) 12 points

(a) Prove

Proposition (Kernel of a Linear Functional). Let (X,k·k) be a normed vector space over F (F := R or F := C). A linear functional f on X is bounded iff kerf is closed.

(b) Give an example showing that, for a linear operator, which is not a linear functional,

the closedness of the kernel is not sufficient for its boundedness.

Grade Distribution:

(a)

“Only if” part

• 1 points Noticing that a bounded linear functional is continuous.

• 1 points Arriving at the conclusion that, by the continuity of f, kerf = f 1 ({0}) is closed. “If” part

• 1 points Choosing the indirect proof by contrapositive and assuming f to be an unbounded linear functional on X.

• 2 points Based on the assumption, choosing a sequence (xn)n2N in X such that

kxnk = 1 and |f(xn)| ! 1, n ! 1. (1)

• 1 points In view of f = 0, choosing an element x 2 X \ kerf and, by the linearity of f, without loss of generality, regarding that f(x) = 1.

• 3 points Setting up the sequence

yn := x xn

f(xn), n 2 N,

and noticing that, by the linearity of f, yn 2 kerf, n 2 N, and that, by (1),

yn ! x /2 kerf, n ! 1.

Applied Operator Theory (MATH 223) Marat Markin, Ph.D. Spring 2019 2

• 1 points By the Sequential Characterization of Closed Sets, concluding that kerf is not closed. (b) 2 points Providing an example of an unbounded linear operator in a Banach space with a closed kernel such as, in the space lp (1  p  1) or (c0,k · k1), the multiplication operator

(xn)n2N 7! Ax := (nxn)n2N with the domain D(A) := c00, which is unbounded, but kerA = {0} is closed.

2. Problem 6 (Problem-Solving Part) 10 points Let (Pn)n2N be a sequence of or- thogonal projections on a Hilbert space (X,(·,·),k · k). Prove that, if, for all x, y 2 X,

(Pnx, y) ! (P x, y), n ! 1,

where P is an orthogonal projection on X, then, for all x 2 X,

Pnx ! Px, n ! 1, in (X,(·,·),k · k).

Grade Distribution:

• 1 points Noticing that, by the premise, for all x 2 X,

(Pnx, x) ! (P x, x), n ! 1.

• 6 points Inferring that, by the idempotency and self-adjointness of orthogonal projection operators, the latter implies that, for all x 2 X,

kPnxk2 ! kPxk2, n ! 1,

and hence,

kPnxk!kPxk, n ! 1. (2)

• 3 points Concluding that, by the Characterization of Convergence in Pre-Hilbert Spaces, the premise along with (2) imply that, for all x 2 X,

Pnx ! Px, n ! 1, in (X,(·,·),k · k).

3. Problem 3 (Theoretical Part) 10 points Prove

Proposition (Joint Continuity of Inner Product). On an inner product space (X,(·,·),k · k), inner product is jointly continuous, i.e., if

X 3 xn ! x 2 X and X 3 yn ! y 2 X, n ! 1, in (X,(·,·),k · k).

then

(xn,yn) ! (x, y), n ! 1.

Grade Distribution:

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• 1 points Setting up

|(xn,yn) (x, y)|, n 2 N.

• 2 points Subtracting and adding inside the absolute value (xn,y) or (x, yn).

• 7 points Using the subadditivity of absolute value, the inner product axioms, the Cauchy-Schwarz inequality, the continuity of norm, and the premise, conclude that

|(xn,yn) (x, y)| ! 0, n ! 1.

Midterm 3, Part B Solutions

Math 232, Fall 2018 Instructor: Dr. Doreen De Leon

1. Suppose we have two species in a given ecosystem, the golden eagle and the fox, where the foxes comprise the main source of food for the eagles. Assume that in the absence of eagles the foxes grow at a rate of 12% per year with a maximum sustainable population of 75,000 (i.e., the carrying capacity). However, in the presence of 15,000 eagles, the growth rate of the fox population decreases by 4% per year. In the presence of 75,000 foxes, the growth rate of the eagles increases by 10% per year. In the absence of any foxes, the eagles have a death rate of 6% per year.

(a) (10 points) Use our standard modeling process to model this as a discrete dynamical

system. (Step 4 is done in part (b)) (b) (10 points) Determine if these two species can coexist in the given ecosystem indefinitely.

Do this in two different ways.

i. Find all of the equilibrium solutions and then use the eigenvalue method for discrete

systems to analyze the stability of all of the relevant equilibrium solution(s). ii. Numerically solve the system using different initial conditions.

Solution:

(a) Step 1: Identify the Problem.

Determine the interaction of the populations of foxes and golden eagles, to determine if it is possible for the two populations to coexist. +2 points for appropriate problem statement. Step 2: Make Simplifying Assumptions.

• Variables

– Fn = population of foxes after n years – En = population of golden eagles after n years – n = number of years – rF = growth rate of foxes (per year) – mE = death rate of golden eagles in the absence of foxes (per year) – θ = minimum viable population of foxes – αF = interaction impact of foxes on eagles (per year) – αG = interaction impact of eagles on foxes (per year)

• Assumptions

– No individuals enter or leave the ecosystem.

1

– In the absence of golden eagles, the population size of foxes is affected by factors, including the current population size and resources (e.g., food, water, land, etc.) – In the absence of golden eagles, the per capita population growth of foxes de- creases as the population size increases, becoming zero when the population reaches the maximum size that can be supported by the environment (i.e., the carrying capacity). – In the absence of foxes, the population size of eagles decreases. – rF = 0.12 – KF = 75000 – – – – dααFE F E n,E= = = n 0.06

75000 15000 0.04 0.1

0 +4 points for list of at least four variables, with units specified, and assump- tions. (1 point off if units missing.) Step 3: Construct the Model. Based on the above assumptions, we obtain the following model.

Fn+1 = Fn + rFFn

✓1 FnKF

◆

αEFnEn

En+1 = En dEEn + αFFnEn.

Plugging in the values for the parameters gives

Fn+1 = Fn + 0.12Fn

✓1 Fn

75000◆ 150000.04

FnEn

En+1 = En dEEn + 750000.10

FnEn.

+4 points for correct model. (b) Step 4: Solve and Interpret the Model

First, we determine the equilibrium values (using Maple), obtaining

• F0 = 0,E0 = 0

• F0 = 75000,E0 = 0

• F0 = 45000,E0 = 18000 This is the relevant equilibrium solution +2 points for correct determination of equilibrium solutions.

i. The only equilibrium solution for which both populations persist is F = 45000,E = 18000. We analyze the stability of the equilibrium solutions by numerically solving the system with different initial conditions (in Maple). Using the eigenvalue method for discrete systems, we define

g1(F, E)=(1+ rF)F 2 rFKF F 2 αEFE g2(F, E) = (1 dE)E αFFE.

Then the Jacobian A is given by

A =

21.12 3.2 · 10-6F 2.66666667 · 10-6E 42.6666667 · 10-6F

1.3333333 · 10-6E 0.94 1.3333333 · 10-6F35.

Evaluating at F = 45000,E = 18000 gives

A =

0.928 0.024 0.12

0.88 ,

having eigenvalues λ1 = 0.964 + 0.04i and λ2 = 0.963 0.04i, both of which are less than 1 in magnitude. Therefore, the equilibrium solution is stable, and we conclude that both populations will persist. +3 points for determination of Jacobian and evaluation of eigenvalues; +3 points for correct interpretation of the results. ii. Solving the system numerically using different initial conditions also indicates that F = 45000,E = 18000 is the only stable equilibrium solution. Therefore, both populations will persist. +2 points for doing numerical solution using at least two different sets of initial conditions.

2. Suppose we have two species in a given ecosystem, the golden eagle and the fox, where the foxes comprise the main source of food for the eagles. Assume that in the absence of eagles the foxes grow at a rate of 12% per year with a maximum sustainable population of 75,000. However, in the presence of 15,000 eagles, the growth rate of the fox population decreases by 4% per year. In the presence of 75,000 foxes, the growth rate of the eagles increases by 10% per year. In the absence of any foxes, the eagles have a death rate of 6% per year. Also assume that the minimum viable population level for foxes is 2,500.

(a) (10 points) Use the five-step modeling process to model this system. Note that Step 4

is done in parts (b)-(d) and Step 5 is done in part (e). Solution: Step 1: Identify the Problem. Determine the interaction of the populations of foxes and golden eagles, to determine if it is possible for the two populations to coexist. +2 points for appropriate problem statement. Step 2: Make Simplifying Assumptions.

• Variables

– F = population of foxes – E = population of folden eagles – rF = intrinsic growth rate of foxes (per year) – mE = death rate of golden eagles in the absence of foxes (per year) – θ = minimum viable population of foxes – KF = carrying capacity of foxes – gF = growth rate of foxes (per year)

FINAL PROJECT RUBRICS

MATH 232, FALL 2018

Rubric for Problem Solving/Modeling

Appropriate definition of relevant variables 1 2 3 4 5

Use of thoughtful assumptions, backed by logical rationale

1 2 3 4 5

Appropriateness of model (e.g., based on background reading, assumptions, etc.)

1 2 3 4 5

Use of appropriate solution techniques to obtain quantitative, qualitative, etc. results

1 2 3 4 5

Accuracy in interpretation of results 1 2 3 4 5

Validation of the model (i.e., sensitivity analysis of relevant parameters, per instructions in problem)

1 2 3 4 5

Rubric for Written Report

Style and format (e.g., abstract, introduction, conclusion, appropriate sections)

1 2 3 4 5

Mechanics (e.g., grammar and punctuation) 1 2 3 4 5

Clarity and organization of ideas 1 2 3 4 5

Quality of mathematical analysis 1 2 3 4 5

Appropriate inclusion of results using mathematical software (e.g., don’t ask the reader to refer to software, but describe significant computations and results)

1 2 3 4 5

Rubric for Oral Report

Clarity of speech (e.g., not mumbling) 1 2 3 4 5

Clarity of explanation 1 2 3 4 5

Organization/flow of oral report 1 2 3 4 5

Identification of main solution points 1 2 3 4 5

Ability to answer questions 1 2 3 4 5

MATH 251, Final Exam Rubric. Spring 2019.

A1: 2 or 3 B1: 10 or 12 B2: 4 C1: 1 or 11 D1: 6

1. Prove that there are exactly four isomorphism classes of groups of order 66.

Proof. Do the abelian case. Get that there is exactly one group of order 66. 1 point.

Use Sylow theorems to get that P11 E G. Use smallest prime index argument to get that P3P11 E G and transitivity of normality for Sylow subgroups to get that P3 E G. Conclude that G is the semidirect product of P2 and P3P11. 2 points.

Analysis of what the possible homomorphisms P2 ! Aut(P3P11) are (this includes to figure what Aut(P3P11) is). Conclude that there are at most three non-abelian groups of order 66. 2 points.

Prove that the three groups obtained are non-isomorphic to each other by using the number of Sylow 2-subgroups in G, or analyzing the kernels of the homomorphisms found, or looking at the orders of elements in G, etc (there are many ways to do this; this is laborious but not super hard). 5 points. ⇤

2. Let |G| = pn, p odd prime and n > 1. Prove:

(a) If H is a non-trivial subgroup of G, then there is x 2 G \ H such that xHx-1 = H. (b) If 1 = N E G then N \ Z(G) = 1. (c) Prove that if G is not cyclic then it contains a subgroup of order p2 that is not cyclic.

Proof. (a) Figure that there are two case to take: if Z(G) ⇢ H and if not. Do the latter case (easy). Mention that the center is non-trivial. 1 point.

Do the former case by taking G/Z(G) and working with H/Z(G) by using induction and the fact that G/Z(G) has a non-trivial center. The elements in this center yield the elements in the normalizer of H. Of course, students have to use the correspondence for this last step. 3 points.

(b) Use the class equation of N to get that the center of N is a subset of the center of G. The idea is a little unnatural, as the class equation is not used much. 3 points.

(c) Use the correspondence between subgroups of G with subgroups of G/Z(G), and use induction (as the order of the quotient is less than the order of G) to get to construct a Zp ⇥ Zp in G. 3 points. ⇤

3. If K is a finite normal subgroup of G and P 2 Sylp(K) then G = NG(P)K.

Proof. Use normality of K to get that all the conjugates of P in G are (Sylow) subgroups of K. 4 points.

Take any g 2 G, use conjugation to get that gPg-1 = kPk-1 for some k 2 K. 2 points.

Prove directly that gk-1 2 NG(P). 3 points.

1

Conclude that G = NG(P)K. 1 point. ⇤

4. (a) Prove that a finite group cannot be the union of the conjugates of a proper subgroup.

(b) Prove that if G is finite and Aut(G) is cyclic, then G is Abelian.

Proof. (a) Realize that they need to use Exercise 4.3.24 in the book. 1 point.

Consider the union of all the conjugates of a maximal subgroup of G containing the proper subgroup. Use Exercise 4.3.24 to get an upper bound on the number of elements in the groups considered in the aforemented union. 3 points.

Reach a contradiction (too many elements in the union). 1 point.

(b) Consider the permutation representation of the action of G on its elements by conjuga- tion. 2 points.

Get that the kernel of the action is the center of the group. 1 point.

Use that G/Z(G) ⇠= Aut(G) to reach the desired result. 2 points. ⇤

6. Let |G| = (pq)2, where p and q are primes such that q = p + 2, and p > 3. Prove that G is

Abelian. Classify these groups.

Proof. Use the Sylow theorems and some basic number theory to get that Pp and Pq are normal in G. 5 points.

Conclude that G is abelian. 1 point.

Use the classification theorem of finitely abelian groups to get all the groups of order (pq)2. 4 points. ⇤

10. Let I be a proper ideal of a ring R.

(a) Show that there is a correspondence between ideals of R/I and ideals of R containing I. (b) Use part (a) to find all the ideals of Zm.

Proof. (a) Use the correspondence for groups to get most of what is requested. 3 points.

Check that the inverse image of an ideal of R/I under the projection homomorphism is also an ideal of R that contains I. 3 points.

(b) Consider Zn ⇠= Z/nZ. The correspondence will yield that all the ideals of this quotient are nothing but images of the ideals of Z under the projection homomorphism. It follows that Zn is a principal ideal ring. 4 points. ⇤

11. Let p(x) = x4 2 2 Q[x]

(a) Construct Q[x]/(p). Prove it is a field. Show what the elements in it look like. (b) Prove that α = x + (p) is a root of p(x), where ̄p is obtained from p by taking quotient in its coefficients. (c) Find the inverse of α.

Proof. (a) Prove that p(x) is irreducible in Q[x] by Eisenstein. Conclude that (p) is maximal and thus that Q[x]/(p) is a field. 2 points.

Analyze what the elements in the quotient look like, and using the degree of p to get that the elements in the field are ‘polynomials’ in α of degree at most three, where α is any root of p(x). 2 points.

(b) Using arithmetic in the quotient (i.e. ‘p is zero’), this is just algebraic manipulation. 3 points.

(c) Use that α4 = 2 to get that α-1 = 12α3. 3 points. ⇤

12. Recall that the ring of Gaussian integers is defined by Z[i] = {a+bi; a, b 2 Z}. It is a C-ring

with 1 under the operations inherited from C. (a) Let p(x) = x2 + 2x + 2 2 Z[x]. Show that Z[x]/pZ[x] is isomorphic to Z[i]. (b) Show that every nonzero ideal of Z[i] must contain a positive integer. Hint: Z[i] ✓ C. What is the length of a “vector” in C?

Proof. (a) Check that p(x) is irreducible in Z[x]. 2 points.

Define the desired isomorphism by finding what element in Z[x]/pZ[x] behaves like i (this is, essentially, a change of basis). Prove the function defined is, in fact, an isomorphism. Alternatively, students may want to use the first isomorphism theorem. 5 points.

(b) The norm of a Gaussian integer will be an element of any ideal containing such element. Students have to realize that this number is obtained by multiplying an element by its conjugate. 3 points. ⇤

MATH 263, Exam 2 (in-class). Assessment rubric

4. Prove in full detail that the continuous image of a compact space is compact.

Solution:

• Let X be compact and f : X ! Y be an (WLOG) onto continuous function. (1 point)

• Let A be an open covering of Y . Since f is continuous, the inverse image, under f, of an open set is also open. It follows that B = {f 1(A); A 2 A} is a family of open sets of X. (5 points)

• B covers X because A covers the range of f. (3 points)

• Since X is compact, we get a finite subcovering of X, given by {f 1(A1),f 1(A2),...,f 1(An)}, where Ai 2 A, for all i. We claim that {A1,A2,...,An} is a finite subcovering of Y . (3 points)

• Clearly all those sets are elements of A. (1 point)

• Since f is onto, if y 2 Y then y = f(x), for some x 2 X. Moreover, X is covered by {f 1(A1),f 1(A2),...,f 1(An)}, and so x 2 f 1(Ai), for some i. It follows that y = f(x) 2 Ai. Since y was arbitrary, we get the subcovering we wanted. (7 points) Total Points: 20

5. A space X has the fixed point property if every continuous function f : X ! X has a fixed point.

(a) Give an example of such a space (prove your claim). (b) Prove that if X has the fixed point property then X must be connected.

Solution: (a)

• Let X = [0,1], and let f : [0,1] ! [0,1] to be a continuous function. Consider the function g(x) = f(x) x. Since f and the identity function are continuous, then so is g. (4 points)

• If f(0) = 0 or f(1) = 1 then we are done. (1 points)

• Assume that f(0) = 0 and f(1) = 1. Since the codomain of f is [0,1], we get that f(0) > 0 and f(1) < 1. It follows that g(0) < 0 and g(1) > 0. (3 points)

• Note that the hypothesis for the intermediate value theorem hold as [0,1] is both connected and has the subspace order topology from R. Hence, g(c) = 0, for some c 2 (0,1), and thus f(c) = c. (3 points) (b)• Assume X = A [ B, a separation. Let a 2 A, b 2 B. We define f : X ! X by

f(x) =

⇢ a if x 2 B b if x 2 A (5 points)

• Clearly f(x) = x, for all x 2 X. (1 point)

• Moreover, f is continuous because if U is open in X then f 1(U) can only be ;, X, A, or B, which are all open in X. (3 points) Total Points: 20

MATH 263, Exam 2 (take-home/oral part). Assessment rubric

1. Clarity of speech and explanation 1 2 3 4 5 2. Clarity of content (is the solution clear) 1 2 3 4 5 3. Organization/Flow 1 2 3 4 5 4. Identification of main ideas 1 2 3 4 5 5. Completeness of solution 1 2 3 4 5 6. Capacity of answering questions 1 2 3 4 5 7. Correctness of solution 1 2 3 4 5

1

MATH 263, Final Exam. Assessment rubrics

1. Let X = R with the topology T given by:

the neighborhoods of a point x are the open intervals containing x, and if x 2 Q, also the set Q. Prove that (R,T ) is Hausdorff but not normal.

Solution:

• The standard topology in R is contained in T (coarser than T ) because T contains the basis for the standard topology. (1 point)

• R with the standard topology is Hausdorff thus, by previous item, so is (R,T ). (1 point)

• Note that Q is open (given) and so A = R Q is closed. Moreover, since (R,T ) is Hausdorff, B = {0} is closed. We want to prove that A and B cannot be separated by disjoint open sets. Let U be an open around A and V an open around B, where U \ V = ;. (1.5 points)

• Clearly, the open sets containing B will contain neighborhoods of 0. So, it is enough to look at V = ( ε,ε), V = Q, or V = ( ε,ε) \Q. If V = ( ε,ε) then we get that V \A = ;, hence there is no way to find open U so that A ⇢ U and U \ V = ;. (2.5 points)

• If V = Q then the only possible way to get U \V = ; is if U ⇢ R Q, but since A = R Q must be contained in U then the only possibility is A = U, and thus that A = R Q is open (clopen, really). This does not happen because all the neighborhoods of elements in A are intervals, and thus (previous item’s idea) they must intersect Q. (2.5 points)

• If V = ( ε,ε) \ Q. The argument here is a mix of the ideas in the two previous items. (1.5 points)

2. Let θ 2 R\Q. Let f : R ! T, where T = R2/Z2, be the function given by f(t)=(t,θt), for all t 2 R.

Prove: (a) f is injective. (b) Let T be the smallest topology in R such that f is continuous. Compare this topology with the standard topology in R. (c) Prove that (R,T ) is connected.

Solution: (a)

• Let θ 2 R\Q be fixed. Suppose that f(x) = f(y), then (x,θx)=(y,θy). This means that both x y and θ(x y) are in Z. This is impossible, because θ /2 Q, unless x y = 0. So, f is injective. (2 points) (b)• If we can prove that f is continuous with the standard topology in R then we would get it to be

finer than T . (1 point)

• Let t0 2 R, and V be an open set containing f(t0). WLOG, we consider f(t0) to not be on the ‘sides’ of the set of representatives [0,1] ⇥ [0,1] (if the point were there, we pick [1/2,1/2] ⇥ [1/2,1/2] as set of representatives). Hence, given V open around f)t0), we can pick a small ε > 0 so that B((t0,θt0),ε) (note the lack of bar over the point) still does not contain points on the ‘sides’ of [0,1] ⇥ [0,1] and that B((t0,θt0),ε) ⇢ V (Note: this restriction is taken to avoid considering many different cases, the same argument still works in all the cases). (2.5 points)

• We want to find open set U so that t0 2 U and f(U) ⇢ V . Consider the intersection of the graph of f with B((t0,θt0),ε) (no bar over the point again). Since B((t0,θt0),ε) is connected then (in R2) the graph of f intersects it in an open interval. Let U be the inverse image of this interval under f. Clearly, f(U) ⇢ B((t0,θt0),ε) ⇢ V . (2.5 points) (c)• Since the standard topology in R is finer than T , it follows that (R,T ) is connected because R

with the standard topology is already connected.(2 points)

1

4. Consider R2 with the order topology. Is Q2 dense in R2?

Solution:

• No, any counterexample would do. Here is a short one. Consider the point P = (π,1) /2 Q2, and the points A = (π,0) and B = (π,2). Clearly the interval (A, B) contains P. Moreover, since the first component of every point on (A, B) is π, none of the points on it belong to Q2. It follows that P /2 Q2, and thus Q2 is not dense in R2. (10 points)

7. Let X be a connected space and f : X ! R continuous. Prove that X is uncountable or that f is a

constant.

Solution:

• If f is a constant. Done. Assume f is not a constant. (1 point)

• Since X is connected and f is continuous, f(X) is connected as well. (2 points)

• f(X) is connected in R, thus it is either an interval or a singleton. The latter case is not possible because f is not a constant. (5 point)

• Intervals are uncountable. Done. (2 points)

**Exit Survey for 2018 Graduating Math Majors**

**Start of Block: Exit survey for graduating math majors**

**Department of Mathematics California State University, Fresno**

Exit survey for 2018 graduating math majors

All questions are optional, but your responses are greatly appreciated. Positive and negative comments are welcome and suggestions for improvement would be particularly useful. This survey is not anonymous and will take approximately 15 minutes. Please respond prior to your scheduled exit meeting with Dr. Amarasinghe and Dr. Vega. Thank you.

1. Name:

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2a. Mailing address:

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2b. Fresno State email:

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2c. Other email:

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2d. Cell phone number and home phone number:

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3a. Graduation year:

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3b. Degree(s) you are graduating with:

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3c. Minor(s) if any:

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4. Are you enrolled or are you planning to enroll in the Single Subject Credential Program? If so, expected completion year?

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5. Are you applying for or considering applying to a graduate program? If so, what program and where? Expected completion year?

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6. What are your current post-graduation plans?

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7. What are your long-term career goals?

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8. Did you work while attending Fresno State? If so, where and in what capacity?

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Did you work full-time or part-time?

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9a. Did you participate in any of the following activities while at Fresno State? Activity (1)

Independent Study in Mathematics (1) o

Research project in Mathematics (2) o

REU (3) o

Math Club (4) o

Putnam Exam (5) o

Integration Bee (6) o

Attended math seminars (7) o

Presented in math seminars (8) o

Volunteered at Math Field Day, Department of Mathematics Day or other similar events.

(9) o

9b. Other activities you participated in:

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9c. What other activities would you be interested in?

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10. What did you like or dislike about the courses you took at Fresno State? Do you have any suggestions for improvement?

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11. Approximately how many times did you meet with your advisor? Was the advising helpful?

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12. What advice would you give to new math majors or students considering becoming math majors?

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13. On a scale from 1 (poor) to 5 (excellent), please rate below the undergraduate program in terms of how well it helped you achieve the following programs goals and student learning outcomes:

A. Provide students with conceptual background knowledge in the core areas of mathematics.

Scale from 1 (poor) to 5 (excellent) (1)

Students will understand and use the definitions and basic properties of fundamental concepts in algebra and analysis, such as function, derivative, integral, matrix, group. (1)

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B. Teach students to read, understand, and write rigorous mathematical proofs.

Scale from 1 (poor) to 5 (excellent) (1)

1. Students will be familiar with common notations and proof techniques. (1)

2. Students will read, understand, and be able to reconstruct rigorous proofs of elementary theorems in various areas of mathematics. (2)

3. Students will be able to write elementary proofs. (3)

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C. Provide students with opportunities to apply mathematical knowledge to solve theoretical and practical problems.

Scale from 1 (poor) to 5 (excellent) (1)

1. Students will use their knowledge of calculus and linear algebra to solve practical application problems. (1)

2. (For credential students) Students will use a variety of problem-solving techniques to solve a wide range of problems of both practical and theoretical nature. (2)

D. Develop students' communication skills, both written and oral, for purposes of conveying mathematical information.

Scale from 1 (poor) to 5 (excellent) (1)

1. Students will be able to explain their solutions and proofs both orally and in writing. (1)

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E. (For credential students) Encourage a positive attitude towards mathematics teaching and learning.

Scale from 1 (poor) to 5 (excellent) (1)

Students will show their excitement and appreciation for the art and science of mathematics. (1)

14. Any comments about the above goals and student learning outcomes?

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15. Any other comments or suggestions regarding the mathematics program at Fresno State?

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Q28 **Thank you for completing our survey! We wish you well in your future endeavors!**

**End of Block: Exit survey for graduating math majors**

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