Course Change Request

New Course Proposal

Date Submitted: 10/14/24 1:45 pm

Viewing: MATH 735 : Computational and Applied Topology

Last edit: 02/26/25 2:23 pm

Changes proposed by: esander

Are you completing this form on someone else's behalf?

No

In Workflow

1. MATH Chair
2. SC Curriculum Committee
3. SC Assistant Dean
4. Assoc Provost-Graduate
5. Registrar-Courses
6. Banner

Approval Path

1. 10/24/24 3:07 pm Maria Emelianenko (memelian): Approved for MATH Chair

Effective Term: Fall 2025

Subject Code: MATH - Mathematics

Course Number: 735

Bundled Courses:

Is this course replacing another course? No

Equivalent Courses:

Catalog Title: Computational and Applied Topology

Banner Title: Computational & App. Topology

Will section titles vary by semester? No

Credits: 3

Schedule Type: Lecture

Hours of Lecture or Seminar per week: 3

Repeatable: Not repeatable (NG) *GRADUATE ONLY*

Default Grade Mode: Graduate Regular

Recommended Prerequisite(s):

Math 631

Recommended Corequisite(s):

Required Prerequisite(s) / Corequisite(s) (Updates only):

Registrar's Office Use Only - Required Prerequisite(s)/Corequisite(s):

And/Or	(	Course/Test Code	Min Grade/Score	Academic Level	)	Concurrency?

Registration Restrictions (Updates only):

Registrar's Office Use Only - Registration Restrictions:

Field(s) of Study:

Class(es):

Level(s):

Degree(s):

School(s):

Catalog Description:

This course gives a basic introduction to computational and applied aspects of topology. It is a combination of topics from geometry, topology, and algorithms and concentrates on topics such as graphs, surfaces, triangulations, complexes, homology, cohomology, duality, Morse theory, persistent homology, spectral sequences, and stability. It is also demonstrated how some of these methods can be used in applied situations and in the study of dynamics.

Justification:

Topological data analysis is one of the fast growing fields at the moment, and courses like this are taught at many universities. For students interested in data sciences, this course is essential.

Does this course cover material which crosses into another department? No

Learning Outcomes:

Learning objectives: Students will learn computational aspects of topology. This includes:

- Learning to compute topology of graphs, surfaces, triangulations, and complexes.
- Learning to work with homology and Morse theory in a computational setting.
- Learning to use persistent homology, and stability, including applications.
- Time permitting, learning to use cohomology, duality, and spectral sequences.

Will this course be scheduled as a cross-level cross listed section? No

Attach Syllabus

m735_syllabus.pdf

Additional Attachments

Staffing:

Thomas Wanner, Ben Schweinhart

Relationship to Existing Programs:

This will strengthen the offerings for the Math PhD students. It allows students to become familiar with a very important interdisciplinary field that has applications throughout science.

Relationship to Existing Courses:

The department has a number of computational courses and a number of topological courses, but this course would be the first that lies in the intersection of these two fields.

Additional Comments:

Reviewer Comments

Key: 18786

Math 735: Applied and Computational Topology

Instructor:	Thomas Wanner
Office:	Exploratory Hall 4404
E-mail:	twanner@gmu.edu
Website:	https://math.cos.gmu.edu/~wanner
Office Hours:	To be announced
Course Modality:	In person
Course Website:	Canvas
Credits:	3
Recommended Prerequisite:	Math 631

Course Description

Topological data analysis is an active field that has seen tremendous growth over the last decade, with a variety of important applications. This course serves as an introduction to this area. We will cover a combination of topics from geometry and topology, such as graphs, surfaces, triangulations, complexes, homology, Morse theory, persistent homology, and stability. In addition, we will study combinatorial topological dynamics, and demonstrate how it can be used to obtain qualitative information about classical dynamics. All necessary mathematical background material will be introduced in detail, and students will obtain access to software to put the theory into action.

Learning Outcomes

By the end of the course, students will be able to:

1. Discuss methods from topological data analysis and combinatorial topological dynamics, and determine when they are appropriate to use.
2. Extract topological information from point clouds and other data sets.
3. Leverage existing computational tools for topological data analysis and combinatorial topological dynamics, which are based on Julia and Python.
4. Appraise recent literature in topological data analysis and combinatorial topological dynamics.

Tentative Course Topics

Week	Topics
	I. Introduction
1	1. Planar Graphs
	2. The Brouwer Degree
2	3. Solving a Maze with Topology
	II. Complexes
	1. Simplicial Complexes
3	2. Convex Set Systems
	3. Delaunay Complexes
4	4. Alpha Complexes
	5. Lefschetz Complexes
	III. Homology
5	1. Chain Complexes
6	2. Homology of Chain Complexes
	3. Matrix Reduction
7	4. Relative Homology
	5. Exact Sequences
	IV. Persistence
8	1. Persistent Homology
9	2. Computing Persistence
	3. Extended Persistence
10	4. Stability Theorems
	5. Application to Pattern Formation
	V. Combinatorial Topological Dynamics
11	1. Discrete Morse Theory
12	2. Multivector Fields
	3. Conley Theory
13	4. Connection Matrices
14	5. Application to Classical Dynamics

This schedule is tentative and might be adjusted during the semester. Any changes will be announced on Canvas.

Course Textbook

The primary textbook for the course is

- H. Edelsbrunner, J.L. Harer: *Computational Topology*, American Mathematical Society, 2010.

In addition, we will draw on selected material from the following texts:

- T. Kaczynski, K. Mischaikow, and M. Mrozek, *Computational Homology*, Springer, 2004.
- K.P. Knudson, *Morse Theory: Smooth and Discrete*, World Scientific, 2015.
- M. Mrozek, T. Wanner, *Connection Matrices in Combinatorial Topological Dynamics*, Springer, 2025.
- J.R. Munkres, *Elements of Algebraic Topology*, Addison-Wesley, 1984.
- N.A. Scoville, *Discrete Morse Theory*, American Mathematical Society, 2019.

Course Policies

Homework Assignments: Homework problems will be assigned once a week and posted on Gradescope. Most of these assignments will be graded and count towards your homework score. While the remaining ones do not have to be handed in, I do advise everyone strongly to study them and write out the solutions properly. I will go through many of the homework problems in the following class and you will not benefit from this if you have not made a serious attempt at solving them.

Final Project and Presentation: Every student has to prepare a final project for the course and present it during a 30 minute presentation. There are two possible types of projects that the students can choose from:

- Read and report on a research paper on topological data analysis or combinatorial topological dynamics.
- Use the methods from class to analyze a specific data set.

Each presentation has to be accompanied by a typed handout of one to two pages.

Late Assignments: In case of illness, please contact the instructor to set up a plan for make-up work. Late assignments will not be accepted unless due to emergency, illness, quarantine, work-related, or other documented reasons.

Grading Policy: Your final grade in the course will be determined from your performance in the homework assignments, a final project/presentation, and your class participation (both in person and on Canvas). Weights for these items will be distributed according to the following schedule:

Homework	Final Project/Presentation	Participation
60%	30%	10%

The assignment of your course grade is based on the total course score, and uses the following grading scale:

Letter Grade	A+	A	A-	B+	B	C	F
Score above	97%	93%	90%	87%	80%	65%	otherwise

If there are any schedule issues related to religious holidays, please inform the instructor the first week of class.

Course Logistics

Content distribution: The course uses Canvas for distributing lecture materials and links to the homework assignemnts. The latter will be submitted and graded via Gradescope. Canvas can be accessed by visiting https://canvas.gmu.edu/ and logging in with your MasonID and password, and there is a link to Gradescope from within the course site.

Communication: I will use Canvas announcemnts to distribute class updates, and Mason e-mail to communicate with students. If you wish, please share your name and gender pronouns with me and how best to address you in class and via email. I use he/him for myself, and you may address me as Tom or Dr. Wanner in email and verbally. Communication over email is largely preferred, and I will respond to student emails promptly within 24 hours.

Course Technology Requirements

Software and Hardware: This course uses Canvas as a learning management system available at https://canvas.gmu.edu/. Students are required to have regular, reliable access to a computer with an updated operating system (recommended: Windows 10 or Mac OS X 10.15 or higher).

Course-specific Software: This course will mostly use Julia, which is available freely from https://julialang.org. An introduction to this language will be given. The course makes use of the free add-on package ConleyDynamics.jl, which was developed by the intructor. For the final projects, students can also use Python, if preferred.

Technical Help: If you have difficulty with accessing Canvas, please contact the ITS Support Center at (703) 993–8870 or support@gmu.edu. If you have trouble with using the features in Canvas, email courses@gmu.edu.

Student Responsibilities

1. Students must use their Mason email account to receive important University information, including communications related to this class. Per University policy, I will not respond to messages sent from or send messages to a non-Mason email address.
2. It is expected that each student will conduct himself or herself within the guidelines of the Honor Code. All academic work should be done with the level of honesty and integrity that this University demands.
3. You are responsible for the accuracy of your own schedule. Check Patriot Web regularly to verify that you are registered for the classes that you think you are. A student who is not registered may not continue to attend class. Faculty are not permitted to grade work of students who do not appear on the official class roster. You are responsible for knowing the last days to drop and add this class.
4. Once the add and drop deadlines have passed, instructors do not have the authority to approve any requests from students to add or drop/withdraw late. It is NOT permissible to drop the class and leave it at that. It needs approval. Late adds (up until the last day of classes) must be reviewed and approved by the department chair of the course being offered. They will be approved only in the case of a documented university error (such as a problem with Financial Aid being processed). All student requests for withdrawals and retroactive adds (after the last day of classes) must be reviewed by the student's academic dean.
5. Once final grades have been recorded, instructors cannot accept any work to change that course grade. Grade changes can only be approved when they are due to a calculation or recording error on the part of the instructor.
6. An IN (incomplete) grade is a very special grade that can only be applied for in writing. It can only be given in cases in which a student is passing a course and has a very limited amount of work left to complete the course.
7. Federal law (a law known as FERPA) requires the protection of privacy of student information. Therefore, no instructor on campus can speak about a student's record with anyone other than the student. The record includes how a student is doing in a course, whether a student has attended class, information about grades, whether a paper has been turned in. Anything. This prohibition includes parents, siblings, and spouses, anyone.

This course adheres to the common course policies set by George Mason University, which includes polices about Academic Standards, Accommodations for Students with Disabilities, FERPA, and Title IX. These policies are described in more detail at the following link: https://stearnscenter.gmu.edu/home/gmu-common-course-policies/.