

Introduction to Combinatorics Fall 2024

MATH 239

Published Sep 05, 2024

Class Schedule

Course	Meet Days	Meet Time	Location	Instructor(s)
MATH 239 001 [LEC]	Mon, Wed, Fri <i>Sep 4 - Dec 3</i>	08:30AM - 09:20AM	MC 1085	P. Haxell <i>pehaxell@uwaterl...</i>
MATH 239 002 [LEC]	Mon, Wed, Fri <i>Sep 4 - Dec 3</i>	01:30PM - 02:20PM	B1 271	O. Mandelshtam <i>olya.mandelshta...</i>
MATH 239 003 [LEC]	Mon, Wed, Fri <i>Sep 4 - Dec 3</i>	10:30AM - 11:20AM	QNC 1502	D. Stebila <i>dstebila@uwaterl...</i>
MATH 239 004 [LEC]	Mon, Wed, Fri <i>Sep 4 - Dec 3</i>	12:30PM - 01:20PM	QNC 2502	J. Leake <i>jonathan.leake@u...</i>
MATH 239 101 [TUT]	Thursdays <i>Sep 4 - Dec 3</i>	04:30PM - 05:20PM	MC 4059	
MATH 239 102 [TUT]	Fridays <i>Sep 4 - Dec 3</i>	09:30AM - 10:20AM	QNC 2502	
MATH 239 103 [TUT]	Thursdays <i>Sep 4 - Dec 3</i>	02:30PM - 03:20PM	MC 4061	
MATH 239 104 [TUT]	Fridays <i>Sep 4 - Dec 3</i>	10:30AM - 11:20AM	MC 4020	
MATH 239 201 [TST]	Tuesday <i>Nov 5</i>	04:30PM - 06:20PM		

schedule data automatically refreshed daily

Instructor & TA (Teaching Assistant) Information

Instructors:

- Penny Haxell <pehaxell@uwaterloo.ca>
- Jonathan Leake <jonathan.leake@uwaterloo.ca>
- Olya Mandelshtam <omandels@uwaterloo.ca> (Course Coordinator)
- Douglas Stebila <dstebila@uwaterloo.ca>

Teaching assistants:

Benjamin Wong	b62wong@uwaterloo.ca (mailto:b62wong@uwaterloo.ca).
Jerónimo Valencia	j2valencia@uwaterloo.ca (mailto:j2valencia@uwaterloo.ca).
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Ian George	i2george@uwaterloo.ca (mailto:i2george@uwaterloo.ca).
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Maryam Mohammadi Yekta	m5mohammadiyekta@uwaterloo.ca (mailto:m5mohammadiyekta@uwaterloo.ca).
Fernanda Rivera Omana	mriveraomana@uwaterloo.ca (mailto:mriveraomana@uwaterloo.ca).

Office Hours

Each instructor will have one office hour per week (starting the week of September 9). The schedule is posted on LEARN, and any changes will be posted as announcements. You are welcome to come to any instructor's office hours, not just your own section.

Piazza

Outside of office hours, Piazza is the primary medium for **all questions** related to the course, except for questions of a personal nature which can be sent to your instructor by email.

The aim is to create a positive learning environment for everyone. Please be professional and courteous. Keep in mind that posts can be made anonymous to other students, but are identifiable to instructors and TA's.

You should use Piazza for:

- Questions and discussion about lectures.
- For assignment problems, you can ask for clarifications, but do not post any full or partial solutions, nor any strong hints. If you have a specific question that include partial solutions to assignment problems, please use private posts.
- Requesting a regrade (private post; see instructions on Regrade Requests below).

Please put some thought into your questions and posts. You should show that you have worked on the problem in some way. A post of the form "I'm stuck, any hints?" is not appropriate.

You are encouraged to help each other and answer questions. For student answers that are correct and do not require additional clarification, the course staff will endorse them without making a further response.

We will aim to provide a prompt response on Piazza, but response times on weekends/holidays may be longer. Piazza will be monitored at least one hour per day Monday to Friday.

Course Description

Calendar Description for MATH 239:

Introduction to graph theory: colourings, matchings, connectivity, planarity. Introduction to combinatorial analysis: generating series, recurrence relations, binary strings, plane trees.

[View requirements for MATH 239 \(https://acal.fast.uwaterloo.ca/course/1249/MATH/239\)](https://acal.fast.uwaterloo.ca/course/1249/MATH/239)

MATH 239 is an introduction to combinatorics and is both fun and useful. This material is closely related to many of the staple puzzle book questions you may have pondered as a kid, and is also foundational to every discipline involving discrete structures including theoretical computer science. The course is primarily theoretical and you will develop your proof-writing skills while working with interesting and useful structures.

The first portion of the course is combinatorial enumeration. If you enjoyed puzzle book questions like "how many ways can you tile a $2 \times n$ board with dominoes?" then you will like this part. If you ever wondered how the number of binary trees grows and how we know that, then you will like this part.

Practically, you will learn about generating series, which are one of the most important tools in algebraic enumeration, particularly with a focus on classes of binary strings as examples of regular languages, and you will learn how to solve recurrence equations. You will play with combinatorial objects like compositions of an integer.

The second portion of the course is graph theory. If you enjoyed puzzle book questions of the form "can you draw a given figure without lifting your pencil or retracing any line?", then you will like this part. If you like to think about the structures of networks then you will like this part. Practically you will learn the formal foundations of graph theory, standard results and how to prove them, and some key graph algorithms.

Learning Outcomes

By the end of this course students should be able to:

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| recognize and work with a variety of combinatorial objects, |
| know standard results and techniques related to them to solve combinatorial problems, and |
| be comfortable writing proofs for results on discrete objects. |

Tentative Course Schedule

This is a tentative schedule with topics that we plan to cover.

Week	Lecture Dates	Topics	Readings	Tutorial Dates	Assessments	Exam coverage
1	September 4, 6	Counting, combinatorial proofs, bijections	EN: 1.1.1-1.1.5	T1: September 12, 13	Assignment 1 due Tuesday, Sept 17	M, F
2	September 9, 11, 13	Generating series	EN: 1.1.5, 2.1-2.2.1 Supplemental notes on formal power series (posted to Learn)	T2: September 19, 20	Assignment 2 due Tuesday, Sept 24	M, F
3	September 16, 18, 20	Sum, product, and string lemmas, integer compositions	EN: 2.2.2-2.3	T3: September 26, 27	Assignment 3 due Tuesday, Oct 1	M, F
4	September 23, 25, 27	Binary strings and string decompositions	EN: 3.1-3.2.3	T4: October 3, 4	Assignment 4 due Friday, Oct 11	M, F
5	September 30, October 2, 4	String recursion, recurrences	EN: 3.3.3.1, 4.1-4.3.1	T5: October 10, 11	on Assignment 5	M, F
6	October 7, 9, 11	Recurrences; introduction to graph theory	EN: 4.3.1 IC: 4.1-4.3	T6: October 24, 25	Assignment 5 due Tuesday, Oct 29	M, F
7	October 14, 16, 18	Reading week			No assignment due	
8	October 21, 23, 25	Bipartite graphs, paths and cycles, connectedness	IC: 4.4-4.6, 4.8	T7: October 31, November 1	on Assignment 6	F

9	October 28, 30, November 1	Eulerian circuits, bridges, trees	IC: 4.9, 4.10, 5.1-5.2	T8: November 7, 8	Midterm Tuesday, Nov 5 Assignment 6 due Tuesday, Nov 12	F
10	November 4, 6, 8	Bipartite characterization, planarity, Euler's formula	IC: 5.3, 7.1, 7.2	T9: November 14, 15	Assignment 7 due Tuesday, Nov 19	F
11	November 11, 13, 15	Platonic solids, nonplanar graphs, Kuratowski's theorem	IC: 7.4, 7.5, 7.6	T10: November 21, 22	Assignment 8 due Tuesday, Nov 26	F
12	November 18, 20, 22	Kuratowski's theorem, colouring, matchings	IC: 7.6, 7.7, 8.1	T11: November 28, 29	Assignment 9 due Tuesday, Dec 3	F
13	November 25, 27, 29	Covers, Konig's theorem, XY-construction, Hall's theorem	IC: 8.2, 8.3, 8.4, 8.6		on Practice Assignment 10	F
14	December 2	Edge colouring, course review	IC: 8.7		on Practice Assignment 10	F

Final exam during the final exam period.

Tutorials

Tutorials will begin on **Thursday, September 12**. These will be primarily interactive problem solving sessions where you work in small groups to solve problems. Tutorials are also a good opportunity to ask questions about assignments and course material.

Graduate student TAs will be leading the tutorials:

Section	STime	Location	TA
101	Thursday 4:30-5:20PM	MC 4059	Lise Turner
102	Friday 9:30-10:20AM	QNC 2502	Massimo Vincenzo
103	Thursday 2:30-3:20PM	MC 4061	Fernanda Rivera Omana
104	Friday 10:30-11:20AM	MC 4020	Harper Niergarth

Texts / Materials

Title / Name	Notes / Comments	Required
(EN) Math 239/249 (Introduction to combinatorics)	notes on enumeration	Yes
(IC) Introduction to Combinatorics (Course notes for Math239)	course notes on enumeration and graph theory	Yes

Two sets of course notes are provided. The first set of notes will be used for only the enumeration part, and is denoted EN in the course schedule. The second set is course notes for the whole course, covering both the enumeration part and the graph theory part; we will be using these for the graph theory part of the course. This set of notes is denoted IC in the course schedule. During the first 5 weeks of the course, in which we will study enumeration, instructors may choose to follow one set or the other more closely at their discretion, but the material in both cases will be essentially the same.

Student Assessment

Grading Scheme A

Component	Value
Individual assignments (Best 7 out of 9)	20%
Midterm exam	30%
Final exam	50%

Grading Scheme B

Component	Value
Individual assignments (Best 7 out of 9)	20%
Final exam	80%

Your grade will be determined automatically as the best of Grading Scheme A and Grading Scheme B. This means that taking the midterm can only help your grade - receiving a 0 grade on the midterm is the same as missing the midterm entirely.

Assignments. Assignments will be **due on Tuesdays at 11:59pm Waterloo time** on Crowdmark.

Roughly speaking, lecture material from week $n-2$ will be in the assignment due in week n . Assignments will be submitted using Crowdmark. The *two* lowest assignment grades will be dropped, to allow for unforeseen circumstances such as illness. Late submissions will receive a grade of 0.

You may ask your instructors or TAs for help during office hours or tutorials. You may also discuss the assignments in small groups, and are encouraged to do so. However, **you must write up the solutions on your own**. This means that you may not write up your solutions while you are with a group, and you should not consult any notes you have taken during your group discussions while writing up your solutions.

Many assignment questions are proof questions and you will be evaluated on the logic and presentation of your ideas. Aim to present your proofs at a level that would be understood by an average student in the class who has not thought about the problem yet.

You may NOT use any materials outside of the following:

- all of the material posted on the MATH 239 Fall 2024 Learn course webpage
- all of the material on the MATH 239 Fall 2024 Piazza webpage
- all of the material presented during lectures, tutorials, office hours or provided to you directly by TAs and instructors.

In particular you may NOT search electronic resources for solutions to assignment questions, use Generative AI (see policy below), or use solutions obtained from previous offerings of this course or any other course. Any submitted assignments that are suspected of cheating will be sent directly to the Integrity Office of the Faculty of Mathematics.

Piazza bonus. Up to 2% will be available as a bonus for positive contributions on Piazza, such as asking good questions or helping answer questions. Use Piazza's "endorsement" mechanism – "good question", "helpful", etc. – to flag good contributions.

Grading scheme. Note: The pass requirement is 50% based on the above formula; there is no requirement to separately pass the midterm or final exam in order to pass the course. However, some programs or subsequent courses may require higher grades for progression, please check the course calendar to see if this applies for you.

Regrade requests. If you believe the grader has made an error in grading your assignment, you may request a regrade. This request must be made in a **private post on piazza** (not via email!) titled 'Regrade Request for Assignment X', and you must provide a **specific reason** for the regrade. Any such request must be made **within 1 week** of receiving the graded assignment. The grader may look at all problems on the assignment and adjust your grade in any or all of them; your grade may go up or down, depending on the grading errors detected. You may not request a regrade of a regraded assignment.

Exams. There will be midterm and final exams that both take place on campus unless the university guidance prohibits in-person exams for public health reasons. The **midterm** will take place on **Tuesday, November 5**; see Odyssey for seat assignments. The final exam will be scheduled by the registrar during the final exam period and will be announced during the term.

Illness and self-declared student absences.

- **Assignments:** There are **no extensions** for assignments, and late assignments will not be accepted. The lowest 2-out-of-9 assignments will be dropped automatically, without penalty. This is the mechanism that will be applied to missed assignments due to illnesses or self-declared student absences. In particular, you do not need to declare your self-declared student absence or notify your instructor to take advantage of dropping the lowest 2-out-of-9 assignments; this will be applied automatically. Furthermore, submitting a VIF or self-declared absence declaration **will not increase the number of assignments you may miss**. For example, if you submit a VIF for missing 3 assignment, your assignment grade will still be calculated from the highest of 7/9 assignments. For another example, if you receive AccessAbility accommodations to skip 3 assignments, your grade will be calculated from the highest of 6/9 assignments, even if you also submit (one or more) VIFs for missing additional assignments.
- **Midterm:** If the midterm exam is missed, the weight of the midterm will be transferred to the final exam. (Keep in mind that missing the midterm is equivalent to taking it and getting a 0 on it.)
- **Final:** If the final exam is missed due to documented illness (using the [Math Faculty's Verification of Illness form](https://uwaterloo.ca/math/accommodations) (<https://uwaterloo.ca/math/accommodations>)) AND the student has a **passing grade in the other two components of the course** (assignments and midterm), an [INC \(incomplete\)](https://uwaterloo.ca/math/accommodations#INC) (<https://uwaterloo.ca/math/accommodations#INC>) grade will be assigned and the student may complete the course by writing the final exam in a later offering of the course. **In particular, if the midterm exam is also missed then there will be no basis for assigning an INC grade.**

Assignment Screening

No assignment screening will be used in this course.

Administrative Policy

Mental health support: Especially in these difficult times, it is important to seek out support if you are struggling. On-campus resources include Campus Wellness, Counselling Services, and the one-on-one peer support program MATES. Off-campus resources include Good2Talk 1-866-925-5454, EMPOWER ME 1-833-628-5589 in Canada and the US, or see http://studentcare.ca/rte/en/IHaveAPlan_WUSA_EmpowerMe_EmpowerMe for other countries. Also OK2BME provides support services for lesbian, gay, bisexual, transgender or questioning youth. Phone 519-884-0000 extension 213 (Waterloo Region only).

Diversity: It is our intent that students from all diverse backgrounds and perspectives be well served by this course, and that students' learning needs be addressed both in and out of class. We recognize the immense value of the diversity in identities, perspectives, and contributions that students bring, and the benefit it has on our educational environment. Your suggestions are encouraged and appreciated. Please let us know ways to improve the effectiveness of the course for you personally or for other students or student groups. In particular: We will gladly honour your request to address you by an alternative/preferred name or gender pronoun. Please advise us of this preference early in the term so we may make appropriate changes to our records. We will honour your religious holidays and celebrations. Please inform of us these at the start of the course. We will follow AccessAbility Services guidelines and protocols on how to best support students with different learning needs.

Generative AI

This course includes the independent development and practice of specific skills which can only be learned through consistent independent work. Therefore, the use of Generative artificial intelligence (GenAI) trained using large language models (LLM) or other methods to produce text, images, music, or code, like Chat GPT, DALL-E, or GitHub CoPilot, is not permitted in this class. Unauthorized use in this course, such as running course materials through GenAI or using GenAI to complete a course assessment is considered a violation of [Policy 71](https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71) (<https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71>) (plagiarism or unauthorized aids or assistance). Work produced with the assistance of AI tools does not represent the author's original work and is therefore in violation of the fundamental values of academic integrity including honesty, trust, respect, fairness, responsibility and courage ([ICAI](https://academicintegrity.org/images/pdfs/20019_ICAI-Fundamental-Values_R12.pdf) (https://academicintegrity.org/images/pdfs/20019_ICAI-Fundamental-Values_R12.pdf), n.d.).

You should be prepared to show your work. To demonstrate your learning, you should keep your rough notes, including research notes, brainstorming, and drafting notes. You may be asked to submit these notes along with earlier drafts of their work, either through saved drafts or saved versions of a document. If the use of GenAI is suspected where not permitted, you may be asked to meet with your instructor or TA to provide explanations to support the submitted material as being your original work. Through this process, if you have not sufficiently supported your work, academic misconduct allegations may be brought to the Associate Dean.

In addition, you should be aware that the legal/copyright status of generative AI inputs and outputs is unclear. More information is available from the Copyright Advisory Committee: <https://uwaterloo.ca/copyright-at-waterloo/teaching/generative-artificial-intelligence> (<https://uwaterloo.ca/copyright-at-waterloo/teaching/generative-artificial-intelligence>).

Students are encouraged to reach out to campus supports if they need help with their coursework including:

- [Student Success Office](https://uwaterloo.ca/student-success/resources) (<https://uwaterloo.ca/student-success/resources>) for help with skills like notetaking and time management
- [Writing and Communication Centre](https://uwaterloo.ca/writing-and-communication-centre/services-0/services-undergraduate-students) (<https://uwaterloo.ca/writing-and-communication-centre/services-0/services-undergraduate-students>) for assignments with writing or presentations
- [AccessAbility Services](https://uwaterloo.ca/accessability-services/students) (<https://uwaterloo.ca/accessability-services/students>) for documented accommodations
- [Library](https://uwaterloo.ca/library/research-supports/quick-start-guide) (<https://uwaterloo.ca/library/research-supports/quick-start-guide>) for research-based assignments

University Policy

Academic integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check [the Office of Academic Integrity](https://uwaterloo.ca/academic-integrity/) (<https://uwaterloo.ca/academic-integrity/>) for more information.]

Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read [Policy 70, Student Petitions and Grievances, Section 4](https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70) (<https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70>). When in doubt, please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline: A student is expected to know what constitutes academic integrity to avoid committing an academic offence, and to take responsibility for their actions. [Check [the Office of Academic Integrity](https://uwaterloo.ca/academic-integrity/) (<https://uwaterloo.ca/academic-integrity/>) for more information.] A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate associate dean. For information on categories of offences and types of penalties, students should refer to [Policy 71, Student Discipline](https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71) (<https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71>). For typical penalties, check [Guidelines for the Assessment of Penalties](https://uwaterloo.ca/secretariat/guidelines/guidelines-assessment-penalties) (<https://uwaterloo.ca/secretariat/guidelines/guidelines-assessment-penalties>).

Appeals: A decision made or penalty imposed under [Policy 70, Student Petitions and Grievances](https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70) (<https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70>) (other than a petition) or [Policy 71, Student Discipline](https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71) (<https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71>) may be appealed if there is a ground. A student who believes they have a ground for an appeal should refer to [Policy 72, Student Appeals](https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-72) (<https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-72>).

Note for students with disabilities: [AccessAbility Services](https://uwaterloo.ca/accessability-services/) (<https://uwaterloo.ca/accessability-services/>), located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.

Turnitin.com: Text matching software (Turnitin®) may be used to screen assignments in this course. Turnitin® is used to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin in this course.

It is the responsibility of the student to notify the instructor if they, in the first week of term or at the time assignment details are provided, wish to submit alternate assignment.

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