

Math 345: Combinatorics

Spring Term 2015

Course Description

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Instructor: John Schmitt

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My (and course) webpage: <http://community.middlebury.edu/~jschmitt/>

Office Hours: Monday 10am–12noon, Tuesday 1:30–3pm, Wednesday 10am–11am, when my office door is open or by arrangement

Meeting times:

Section A, MWF, 9:05am–9:55 am, Warner Hall 506

Overview:

The study of Combinatorics involves the following. Given a finite set of objects and a set of rules placed upon these objects, we ask two questions:

1. Does there exist an arrangement of the objects that satisfy the rules? This is the question of **existence**.
2. If such an arrangement exists, how many are there? This is the question of **enumeration**.

At times one of these questions can be trivial to answer and the other fiendishly difficult. Our focus mostly will be on aspects of enumeration, though we will spend some time with the existence question via design theory and the polynomial method. I hope to highlight my favorite area: extremal combinatorics, which deals with understanding the structure of combinatorial objects satisfying some given property and that are as ‘large’ or ‘small’ as possible. Questions from graph theory are considered in MATH 0247.

Textbook: *Introductory Combinatorics, Fifth Edition* by Richard Brualdi, Prentice Hall, NJ, 2008.

Supplemental texts available in Davis Family Library

- *A Course in Combinatorics*, Van Lint and Wilson
- *Enumerative Combinatorics*, R. Stanley
- *Introductory Combinatorics*, K. Bogart
- There are many others.

Homework: Homework will be assigned on a weekly basis. The content of this course is best learned by *practicing problems*. I **encourage you to work together**. However, the write-up of homework solutions *should be done on your own*. Please see the accompanying “thoughts” on homework.

Also, beginning with the third homework assignment, you will need to have at least one problem from each assignment typeset using the mathematical typesetting tool \LaTeX . In asking this of you, I assume that as you are enrolled in this you have a future in the mathematical sciences. This tool is indispensable for such a future. \LaTeX is available for the Mac via TeXShop, available for free download here, <http://pages.uoregon.edu/koch/texshop/>. For those with a PC, MikTeX and TexnicCenter are available from the following locations <http://miktex.org/2.9/setup> and <http://www.texniccenter.org/resources/downloads/29>.

Special Needs: If you require special arrangements for class or during tests/exams please talk to me as soon as possible to make such arrangements. Also, please inform me if you are color-blind as the use of colors can be an important part of a lecture.

Grading percentages:

Homework	25
Midterm 1	25
Midterm 2	25
Midterm 3 (Final)	25

Assignment of grades:

The assignment of grades will follow the scheme below.

90 and above	A
80 - 89	B
70 - 79	C
60 - 69	D
below 60	F

Plus and minus will be determined at the end of the semester.

Midterm exam schedule:

(tentatively) Thursday evening, March 12, 7:30–9:30pm

Thursday evening, April 16, 7:30–9:30pm

(I will be attending a combinatorics workshop March 12–15 in Richmond, VA.)

Final exam:

Friday, May 15 9am–12pm.

This is the only time the exam will be administered, please make plans accordingly.

Open problems:

Mathematics is a living subject. According to the celebrated mathematician Paul Erdős, the point of life is “to prove and conjecture.” Therefore, anyone solving an unsolved problem in combinatorics (including graph theory) will automatically receive an A for the course. The problem must appear in a peer-reviewed mathematics publication (or approved website) and you must be “current” with all your work.

Approved websites include:

- <http://garden.irmacs.sfu.ca>
- <http://www.math.uiuc.edu/~west/openp/>
- http://www.dmoz.org/Science/Math/Combinatorics/Graph_Theory/Open_Problems/

Our textbook author: The author of the text, Richard Brualdi, has a website <http://www.math.wisc.edu/~brualdi/>, with a link for info and updates on our text. Anyone finding a previously unreported typo or error in the text will receive 1 percentage point bonus on an exam.

Absences: Please see me as far in advance as possible for absences that will occur on the day of an exam. Any such absences, or unforeseen ones, must be documented in writing by the appropriate person.

Honor Code: The Honor Code will be observed throughout this class and for all examinations. Exams will be “closed notes, closed books,” unless otherwise noted. If you have a question about how the Honor Code applies to this class, please ask. In particular, failure to comply with the homework policy (see above) will be considered a violation of the Honor Code.

Outline of Topics

1. Introductory Problems
Chessboard covers, magic squares, Euler's 36 officers, and others
2. Permutations and Combinations
Basic counting principles
3. The Pigeonhole Principle
Simple and strong form, and Ramsey's Theorem
4. Generating Permutations and Combinations
5. The Binomial Coefficients
Pascal's formula, the binomial theorem
6. Principle of Inclusion-Exclusion
7. Recurrence Relations and Generating Functions
8. Special Counting Sequences
Catalan and Stirling numbers
9. Combinatorial Designs
Block designs, triple systems and latin squares
10. Pólya Counting (if time permits)
Burnside's lemma, Pólya's counting formula
11. The Polynomial Method (if time permits)
The Combinatorial Nullstellensatz and (fun) applications

Goals of the Course

- gain an understanding of the fundamental concepts of combinatorics,
- gain an understanding of how counting arguments may be used within mathematics,
- develop the ability to write a logical and coherent proof,
- introduce topics suitable for a senior thesis,
- develop a desire for further study in related areas, including graph theory and computer science,
- gain an appreciation for combinatorial applications to the physical, biological and social sciences, etc.,

- appreciate the beauty and sophistication of combinatorial arguments,
- have fun!