Course Guidelines | Combinatorics
University of Puget Sound | Math 420
Dr. Beezer | Fall 2016

Texts There are numerous open textbooks for combinatorics and graph theory, and I am working on an introductory manuscript about block designs. So course material will be backed by a variety of sources. I will keep you informed in class about particular sections that I recommend for each topic. Electronic versions of this syllabus contain links to each book, other than the first one. Those books with useful HTML versions contain an additional link.

- Beezer, introductory *Block Designs* manuscript, to be provided
- Keller and Trotter, Applied Combinatorics [HTML]
- Levin, Discrete Mathematics: An Open Introduction [HTML]
- Guichard, An Introduction to Combinatorics and Graph Theory [HTML]
- Doerr and Levasseur, Applied Discrete Structures [HTML]
- Cusack, Active Introduction to Discrete Mathematics and Algorithms
- Bogart, Combinatorics Through Guided Discovery
- Smid, Discrete Structures for Computer Science
- Bondy and Murty, Graph Theory With Applications

Course Web Page Off of buzzard.ups.edu/courses.html you can find the link to the course web page.

Office Hours My office is in Thompson 303. Making appointments or simple, **non-mathematical** questions can be handled via email — my address is beezer@ups.edu. I rarely do not receive your email, and I read all of my email all of the time, usually very shortly after receiving it. Urgency of replying varies by the hour, day and nature of the message. Office Hours are (tentatively) 2:00–2:50 on Monday and Friday, 10:30–11:30 on Tuesday and Thursday. Office Hours are first-come, first-served, so I do not make appointments for these times, nor do you need to ask me if I will be present at these times. You may assume I will be there, unless I have

announced otherwise in class or by email. You **may** make an appointment for other times, or just drop by my office to see if I am in. Office Hours are your opportunity to receive extra help or clarification on material from class, or to discuss any other aspect of the course.

Calendar The course is organized into four units:

- Basic Counting Techniques (12 lectures)
- Advanced Counting Techniques (12 lectures)
- Graph Theory (11 lectures)
- Block Designs (7 lectures)

Start and stop dates are indicated on the attached tentative calendar.

Computation Combinatorics (and graph theory), as part of **discrete mathematics**, is a natural area to explore with the aid of computational tools. I will keep you informed of ways that you can use Sage (an open source program for advanced mathematics) to aid your study. The book by Bard is a very helpful general resource, while the other two may be helpful but are not directly aligned with our course.

- Bard, Sage for Undergraduates
- Beezer and Godsil, Explorations in Algebraic graph Theory with Sage
- Joyner, Van Nguyen, and Cohen, Algorithmic Graph Theory

Practice Exercises will be suggested regularly as part of each unit. Of course, you are not limited to working **just** these assigned problems and you can find many more in textbooks in the library (ask me for suggestions). We have seven class days reserved for discussions when we can talk about these problems. It is your responsibility to be certain that you are learning from the homework exercises. The best ways to do this are to work the problems diligently, start studying them early, and participate in the classroom discussion. If at this point you are still unsure about a problem, then a visit to my office is in order, since you are obviously not prepared for the examination questions. Making a consistent effort outside of the classroom is the easiest way (only way?) to do well in this course.

> Mathematics not only demands straight thinking, it grants the student the satisfaction of knowing when he [or she] is thinking straight.
>
> —D. Jackson

> Mathematics is not a spectator sport.
>
> —Anonymous

> I hear, I forget. I see, I remember. I do, I understand.
>
> —Chinese Proverb

> An education is not received. It is achieved.
>
> —Anonymous

Examinations There will be four 50-minute timed examinations. Planned dates are all listed on the **tentative** schedule. The comprehensive final examination will be given at Noon on Wednesday, December 14. The final exam cannot be given at any other time, so be certain that you do not make any travel plans that conflict, and also be aware that I will allow you to work longer on the final exam than just the two-hour scheduled block of time.

Grades Grades will be based on the following breakdown:

- Examinations: 70%
- Final Examination: 30%

Attendance and improvement will be considered for borderline grades, while excessive attendance and late-arrival problems will result in grade penalties. Scores will be posted anonymously on the web at a link off the course page.

Academic Policy Reminders Here are three reminders about important academic policies contained in the *Academic Handbook*. These are described thoroughly online at http://www.pugetsound.edu/student-life/student-handbook/academic-handbook/, or a printed copy may be requested from the Registrar's Office (basement of Jones Hall).

Registration for Courses of Instruction, Non-Attendance "Regular class attendance is expected of all students. Absence from class for any reason does not excuse the student from completing all course assignments and requirements."

Grade Information and Policy, Withdrawal Grades Withdrawal grades are often misunderstood. A Withdrawal grade (W) can only be given prior to the university deadline listed on our course schedule, and after that time (barring unusual circumstances), the appropriate grade is a Withdrawal Failing (WF), **even if your work has been of passing quality**. See the attached schedule for the last day to drop with an automatic 'W'.

Academic Integrity All of your graded work is expected to be ***entirely*** your own work, this includes Reading Questions and Sage Exercises. Anything to the contrary is a violation of the university's comprehensive policy on Academic Integrity (cheating and plagiarism). Discovered incidents will be handled strictly, in accordance with this policy. Penalties can include failing the course and range up to being expelled from the university.

Purpose At this point in your college career, you should be well on your way to being an independent scholar, who appreciates the beauty of mathematics and understands the effort needed to master new and difficult ideas. Consistent with that, I will be giving you more freedom than usual to learn this material in a manner that suits you. Of course, with freedom comes responsibility.

Study the material before the lectures, work the exercises early and diligently, tidy up your class notes each evening, and ask questions. Arriving late to class, or having conversations with others during class, not only disrupts your peers, but tells me you are not serious about your education.

Combinatorics is important for many problems in computer science and allied fields (like cryptology), is fundamentally the main part of simple probability questions, and is useful in other fields of mathematics, such as abstract algebra. Many optimization questions (scheduling, vehicle routing, etc.) rely heavily on ideas from combinatorics. Its also a major component of problems classified as recreational mathematics (puzzles and games).

Conduct Daily attendance is required, expected, and overall a pretty good idea. Class will begin on-time, so be here, settled-in and ready to go. In other words, walking in the door at the exact

time class is to begin is not considered arriving on-time. Repeated tardieness and absences will result in grade penalties, in accordance with university policies. Do not leave class during the lecture unless your continued presence would be a greater interuption — fill your water bottles, use the toilet, and so on, **in advance**. I do not care how much food or drink you bring to class, so long as it does not distract others or make me hungry. Please do not offer me sweets. Please keep phones in your pocket or bag, unless you are using them to read course material. In short, we are here to learn and discuss mathematics together. It is your responsibility to not distract your peers who are serious about their education or distract me as I endeavor to make the best use of the class time for you and your colleagues.

University Notices These are two notices the university administration requests we relay to you.

Student Accessibility and Accommodation "If you have a physical, psychological, medical or learning disability that may impact your course work, please contact Peggy Perno, Director of the Office of Accessibility and Accommodation, 105 Howarth, 253.879.3395. She will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential."

I request that you give me at least two full working days to respond to any requests from this office.

Classroom Emergency Response Guidance Please review university emergency preparedness and response procedures posted at http://www.pugetsound.edu/emergency/. There is a link on the university home page. Familiarize yourself with hall exit doors and the designated gathering area for your class and laboratory buildings.

If building evacuation becomes necessary (e.g. earthquake), meet your instructor at the designated gathering area so she/he can account for your presence. Then wait for further instructions. Do not return to the building or classroom until advised by a university emergency response representative.

If confronted by an act of violence, be prepared to make quick decisions to protect your safety. Flee the area by running away from the source of danger if you can safely do so. If this is not possible, shelter in place by securing classroom or lab doors and windows, closing blinds, and turning off room

lights. Lie on the floor out of sight and away from windows and doors. Place cell phones or pagers on vibrate so that you can receive messages quietly. Wait for further instructions.

Tentative Daily Schedule

Monday	Tuesday	Thursday	Friday
Aug 29 Syllabus Start Unit: Basic Counting	Aug 30	Sep 1	Sep 2
Sep 5 Labor Day	Sep 6	Sep 8	Sep 9
Sep 12 Discussion Drop w/out Record	Sep 13	Sep 15	Sep 16
Sep 19	Sep 20	Sep 22 Discussion	Sep 23 Exam 1 Basic Counting
Sep 26 Start Unit: Advanced Counting	Sep 27	Sep 29	Sep 30
Oct 3	Oct 4	Oct 6	Oct 7
Oct 10 Discussion	Oct 11	Oct 13	Oct 14

Mid-Term

Tentative Daily Schedule

Monday	Tuesday	Thursday	Friday
Oct 17 Fall Break	Oct 18 Fall Break	Oct 20	Oct 21 Discussion
Oct 24 Exam 2 Advanced Counting	Oct 25 Start Unit: Graph Theory	Oct 27	Oct 28
Oct 31	Nov 1	Nov 3	Nov 4 Drop w/ Auto W
Nov 7 Discussion	Nov 8	Nov 10	Nov 11
Nov 14	Nov 15 Discussion	Nov 17 Exam 3 Graph Theory	Nov 18 Start Unit: Block Designs
Nov 21	Nov 22	Nov 24 Thanksgiving	Nov 25 Thanksgiving
Nov 28	Nov 29	Dec 1	Dec 2
Dec 5 Discussion	Dec 6 Exam 4 Block Designs	Dec 8 Reading Period	Dec 9 Reading Period

Final Examination: Wednesday, December 14, Noon

Topics and Texts

Topic	KT	L	G	DL	B
Introduction	1	0.1	1.1		
(Binary) Strings	2.1	1.2		1.4	
Addition Principle		1.1	1.2	2.3	
Multiplication Principle		1.1	1.2	2.1	
Permutations	2.2	1.3	1.2	2.2	
Combinations	2.3	1.2	1.2	2.4.1	
Ordered Set Partitions	2.7		1.5		
Ordered Integer Partitions		1.5	1.5		
Binomial Coefficients	2.5, 2.6	1.2	1.3	2.4.2	
Multinomial Coefficients	2.7				
Inclusion-Exclusion	7	1.6	2		
Set Partitions			1.8		
Recurrence Relations	9	2	3.4	8	
Generating Functions	8	5.1	3	8.5	
Graph Theory Basics	5.1	4.1	4.4, 5.1	9.1	
Eulerian, Hamiltonian	5.3	4.4	5.2, 5.3	9.4	
Trees			5.5	10	
Planarity	5.5	4.2	5.10	9.6	
Coloring	5.4	4.3	5.4, 5.8, 5.10	9.6	

- KT = Keller and Trotter
- L = Levin
- G = Guichard
- DL = Doerr and Levasseur
- B = Beezer

Suggested Exercises

Topic	Exercises
Introduction	Discern Floor 4 tile patterns
Addition, Multiplication Principles	L.1.1.1, L.1.1.2, L.1.1.3, L.1.1.4, L.1.1.11, L.1.1.13
	G.1.2.3, G.1.2.5
	DL.2.3.10, DL.2.1.2, DL.2.1.3, DL.2.1.5
Permutations and Combinations	KT.2.9, 1–14
	L.1.3, 1–14
	G.1.2, 1–7
	DL.2.4.5, 1–4, 7–11, 13, 14, 16, 18
Ordered Set Partitions	KT.2.9, 31, 32
Ordered Integer Partitions	L1.5, 1-4, 7-9, 11
Binomial, Multinomial Coefficients	KT.2.9, 20, 21, 29, 30
	L.1.2, 8, 9, 13
	G.1.3, 2, 3, 5, 7, 8, 9, 11, 12, 13, 15–18
Inclusion-Exclusion	KT.7.7, 1–21
	L.1.6, 1–11
	G.2.1, 2
Recurrence Relations	KT.9.8, 2, 3, 4, 11, 13
	L.2.4, 1–12
	G.3.4, 1–9
	DL.8.3.5, 1–9, 16
Generating Functions	KT.8.8, 2, 3, 4–19
	KT.9.9, 15, 16, 17
	L.5.1, 1, 2, 5, 8, 9, 10, 13, 14, 15
	G.3.1, 4, 5, 6, 7, 9
	DL.8.5.7, 1–6, 9, 10
Graph Theory Basics	KT.5, 1–5, 7
	L.4.1, 1–6, 8
	G.5.1, 1–12
Eulerian, Hamiltonian	KT.5, 8–12
	L.4.4, 1–11
	G.5.2, 1–4
	G.5.3, 1–3
	DL.9.4, 1–6
Trees	KT.5, 6, 36, 37–42
	G.5.5, 1–6
	DL.10.1, 1–5
Planarity	KT.5, 29–32
	L.4.2, 1–10
	DL TBA
Coloring	KT.5, 13–17
	L.4.1, 6, 7
	L.4., 1–11
	G.5.4, 2, 3
	G.5.8, 1–4
	G.5.10, 1
	DL TBA

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