JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Computer Science 601.430/630
COMBINATORICS AND GRAPH THEORY IN COMPUTER SCIENCE
Spring, 2025 (3 credits, EQ)

Instructor

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Teaching Assistant

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Office hours: Fridays 3:00–4:00 pm, in person.

Meetings

Tuesday and Thursday, 1:30–2:45 pm, Hodson 313

Textbook

Required: Stasys Jukna, *Extremal Combinatorics: With Applications in Computer Science*. 2nd Edition.

Recommended: N. Alon and J. H. Spencer, The Probabilistic Method. 4th Edition.

Online Resources

Any related online material will be posted at the course website http://www.cs.jhu.edu/~lixints/class/spring25.html or in Canvas.

Course Information

- This is a combined graduate and undergraduate level course studying the applications of combinatorics and graph theory in computer science. We will start with some basic combinatorial techniques such as counting and pigeon hole principle, and then move to advanced techniques such as the probabilistic method, spectral graph theory and additive combinatorics. We shall see their applications in various areas in computer science, such as proving lower bounds in computational models, randomized algorithms, coding theory and pseudorandomness. Students may receive credit for only one of EN.601.430 and EN.601.630.
- **Prerequisites**
  Discrete Math or permission. Probability theory and linear algebra strongly recommended.
- **Selective Elective**

Course Goals

Specific Outcomes for this course are that:

- Students will learn to establish a formal foundation of the theory of computation.
- Students will learn to analyze and solve problems formally and mathematically.

This course will address the following Criterion 3 Student Outcomes:

- An ability to apply knowledge of computing and mathematics appropriate to the discipline (a)
- An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution (b)

Tentative Course Topics

- Basic Techniques: Counting; Pigeon hole principle; Matching and Hall's theorem; Chains and Antichains, with applications to LIS.
- The Probabilistic Method: Basic method; Lovaz local lemma and its constructive proof; Linearity of Expectation; The deletion method; Concentration bounds; Random walks and randomized algorithm for finding satisfying assignment for 2-CNF.
- Spectral Graph theory: Basic properties of graph spectrum; Cheeger's inequality and approximation of graph expansion; Expander graphs and applications to superconcentrators and pseudorandomness; Error correcting codes and expander codes.
- Ramsey Type Theorems and Constructions of Ramsey Graphs.
- Additive Combinatorics: Sum product theorem, Szemeredi-Trotter theorem, Kakeya set problem and applications to randomness extractors.

Who should Take this Course

Students who have strong math background and math skills, and who are interested in theoretical computer science/combinatorics and graph theory are encouraged to take this course.

Who should not Take this Course

Students who don't have a strong math background, math skills, or strong interests in theoretical computer science/combinatorics and graph theory should not take this course. Specifically, just feeling your math background is not *weak* is not sufficient for taking this class. In addition, there will be a lot of formal definitions, math proofs, and abstraction in this course. If you have difficulties with these (e.g., you always need to look at specific graphs in order to think about a graph theoretical problem), then you should not take this class. Otherwise it's just going to be a hard time for everyone.

Course Expectations & Grading

There will be four or five homework problem sets, one mid-term exam and one final exam. Grading will be based on the following rule:

- Homework: 40%.
- Mid-term exam: 30%.
- Final exam: 30%.

Key Dates

The mid-term exam will be held on March 13. The final exam will be cumulative and be held on date TBD. The specific formats of the exams (either on-line or in person) will be decided later. No make-up exams will be given, unless you have legitimate reasons, so plan accordingly. If the exams are held in person, for the midterm, you may bring a single, 8.5x11 inch, handwritten sheet of paper (you may use both sides). For the final exam you may bring two sheets. No calculators are allowed (they won't be necessary).

Assignments & Readings

Assignments and further readings will be posted on the course website http://www.cs.jhu.edu/~lixints/class/spring25.html or in Canvas.

Homework will be submitted and graded in Gradescope, integrated with Canvas.

Online discussion will be held in Piazza, integrated with Canvas.

Ethics

The strength of the university depends on academic and personal integrity. In this course, you must be honest and truthful, abiding by the *Computer Science Academic Integrity Policy*:

> Cheating is wrong. Cheating hurts our community by undermining academic integrity, creating mistrust, and fostering unfair competition. The university will punish cheaters with failure on an assignment, failure in a course, permanent transcript notation, suspension, and/or expulsion. Offenses may be reported to medical, law or other professional or graduate schools when a cheater applies.
>
> Violations can include cheating on exams, plagiarism, reuse of assignments without permission, improper use of the Internet and electronic devices, unauthorized collaboration, alteration of graded assignments, forgery and falsification, lying, facilitating academic dishonesty, and unfair competition. Ignorance of these rules is not an excuse.
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> Academic honesty is required in all work you submit to be graded. Except where the instructor specifies group work, you must solve all homework and programming assignments without the help of others. For example, you must not look at anyone else's solutions (including program code) to your homework problems. However, you may discuss assignment specifications (not solutions) with others to be sure you understand what is required by the assignment.
>
> If your instructor permits using fragments of source code from outside sources, such as your textbook or on-line resources, you must properly cite the source. Not citing it constitutes plagiarism. Similarly, your group projects must list everyone who participated.
>
> Falsifying program output or results is prohibited.
>
> Your instructor is free to override parts of this policy for particular assignments. To protect yourself: (1) Ask the instructor if you are not sure what is permissible. (2) Seek help from the instructor, TA or CAs, as you are always encouraged to do, rather than from other students. (3) Cite any questionable sources of help you may have received.

On every exam, you will sign the following pledge: "I agree to complete this exam without unauthorized assistance from any person, materials or device. [Signed and dated]". Your course instructors will let you know where to find copies of old exams, if they are available.

[In addition, the specific ethics guidelines for this course are:

(1) *Collaboration policy:* While you should first think about homework problems on your own, I encourage you to discuss homework problems with your classmates. However, you must write up your own solutions. Students found sharing the same paragraph in their homework will receive 0 point for the homework, and risk further punishment such as automatic failure and report to the University. Furthermore, you must acknowledge any collaboration by writing the names of your collaborators on the front page of the assignment. You don't lose points by having collaborators.

(2) *Using other resources:* You can use other resources (e.g., online resources) to help you understand the topics generally. However, using resources other than those provided in class (textbook, notes, homework solutions) in your homework or exams is prohibited. Using unauthorized solutions from other resources in homework or exams is considered plagiarism and will result in 0 point for the assignments and potential further punishment as in (1).

To clarify, unauthorized resources for homework or exams include artificial intelligence (AI) assistants such as ChatGPT and GitHub Copilot. Therefore, use of such AI assistants in homework and exams is not allowed in this course.

(3) *Late Policy:* You have a total of two late days without penalty for the homework. A day here means 24 hours. For example, if the deadline is 7pm, then one day means from 7pm to 7pm next day, and any time after 7pm the first day until 7pm the next day is counted as one day. You can use your two late days freely, e.g., one late day for one homework and one for another, or two late days for one homework. Once you use up your late days, your late homework will not be graded, unless you have legitimate reasons.

Report any violations you witness to the instructor.

You can find more information about university misconduct policies on the web at these sites:

- For undergraduates: the director of student conduct (or designee) by calling the Office of Student Conduct at 410-516-2509 or via email at studentconduct@jhu.edu
- For KSAS Graduate Students: rseitz5@jh.edu
- For WSE Graduate Students: christinekavanagh@jhu.edu

Personal Wellbeing

- If you are sick please notify me by email as soon as possible so that we can make appropriate accommodations should this affect your ability to attend class, complete assignments, or participate in assessments. *Illness requests after the deadline of assignments will not be accepted, and in that case your assignments will not be accepted or graded if they are not submitted by the deadline*. The Student Health and Wellness Center(https://studentaffairs.jhu.edu/student-health/) is open and operational for primary care needs. If you would like to speak with a medical provider, please call 410-516-8270, and staff will determine an appropriate course of action.
- Johns Hopkins University values diversity and inclusion. We are committed to providing welcoming, equitable, and accessible educational experiences for all students. Students with disabilities (including those with psychological conditions, medical conditions, and temporary disabilities) can request accommodations for this course by providing an Accommodation Letter issued by Student Disability Services (SDS). Please request accommodations for this course as early as possible to provide time for effective communication and arrangements.

For further information or to start the process of requesting accommodations, please contact Student Disability Services at Homewood Campus, Shaffer Hall 101, call: 410-516-4720 and email: studentdisabilityservices@jhu.edu or visit the website https://studentaffairs.jhu.edu/disabilities/.

- If you are struggling with anxiety, stress, depression, or other mental health related concerns, please consider visiting the JHU Counseling Center. If you are concerned about a friend, please encourage that person to seek out their services. The Counseling Center is located at 3003 North Charles Street in Suite S-200 and can be reached at 410-516-8278 and online at http://studentaffairs.jhu.edu/counselingcenter/
- Student Outreach & Support helps students manage physical and mental health concerns, personal and family emergencies, financial issues, and other obstacles that may arise during their college experience. Students can self-refer or refer a friend who may need extra support or help getting connected to resources. To connect with SOS, please please visit this website: https://studentaffairs.jhu.edu/student-life/student-outreach-support/ or email deanofstudents@jhu.edu, call 410-516-7857, or students can schedule to meet with a Case Manager by visiting the Student Outreach & Support website and filling out a referral form online.

Classroom Climate

Johns Hopkins University is committed to creating a classroom environment that values the diversity of experiences and perspectives that all students bring. Everyone here has the right to be treated with dignity and respect. I believe fostering an inclusive climate is important because research and my experience show that students who interact with peers who are different from themselves learn new things and experience tangible educational outcomes. Please join me in creating a welcoming and vibrant classroom climate. Note that you should expect to be challenged intellectually by me, the TAs, and your peers, and at times this may feel uncomfortable. Indeed, it can be helpful to be pushed sometimes in order to learn and grow. But at no time in this learning process should someone be singled out or treated unequally on the basis of any seen or unseen part of their identity.

If you ever have concerns in this course about harassment, discrimination, or any unequal treatment, or if you seek accommodations or resources, I invite you to share directly with me or the TAs. I promise that we will take your communication seriously and to seek mutually acceptable resolutions and accommodations. Reporting will never impact your course grade. You may also share concerns with the Department Head (Randal Burns, randal@cs.jhu.edu), the Director of Undergraduate Studies (Joanne Selinski, joanne@cs.jhu.edu), the Assistant Dean for Diversity and Inclusion (Darlene Saporu, dsaporu@jhu.edu), or the Office of Institutional Equity (oie@jhu.edu). In handling reports, people will protect your privacy as much as possible, but faculty and staff are required to officially report information for some cases (e.g. sexual harassment).

Family Accommodations Policy

You are welcome to bring a family member to class on occasional days when your responsibilities require it (for example, if emergencychild careis unavailable, or for health needs of a relative). In fact, you may see my children in class on days when their school is closed. Please be sensitive to the classroom environment, and if your family member becomes uncomfortably disruptive, you may leave the classroom and return as needed.

Policy on Incomplete Grades The full policy is available here: https://e-catalogue.jhu.edu/engineering/full-time-residential-programs/undergraduate-policies/academic-policie grading-policies/

The following text is an excerpt:

(1) A request for an Incomplete grade must be initiated by the student no later than the last day of classes via the Incomplete Grade Contract available in SIS
(2) The required elements on the Incomplete Grade Contract are listed below; all of these topics should be included in the conversation between the student and the instructor.
    - The reason for the request for an incomplete grade
    - A description of all outstanding work that must be completed
    - Date the work is due from the student
    - The reversion grade if the student does not complete any of the outstanding work
(3) Instructors are required to submit the new grade to the Office of the Homewood Registrar no later than 45 calendar days after the last day of classes. If the Incomplete grade is not resolved within 45 calendar days after the last day of classes, the Incomplete grade is automatically converted to the reversion grade.

The significant component of this policy is that there is an Incomplete Grade Contract available to students in SIS to request an incomplete grade. This is how all incomplete grades must be initiated. Another significant component is the timeline for completion of an incomplete grade for undergraduate students, which is *45 calendar days after the last day of classes*. For graduate students, the deadline is the end of the third week of classes of the following semester. See the full catalogue entry for considerations for students on academic probation and graduating students.

Deadlines for Adding, Dropping and Withdrawing from Courses https://studentaffairs.jhu.edu/registrar/students/registration/