C SCI 220 / 620: Discrete Structures (M W 8:00 pm Section)

Instructor: Dr. T. Yung Kong  (tkong@qc.cuny.edu)

Office Hours:  Mon. & Wed. 3:25 – 4:00 pm in SB A106  Mon. & Wed. 9:20 – 9:45 pm in PH 113

Important documents (including a possibly updated version of this document) and lecture slides will be posted to https://phantom.cs.qc.cuny.edu/kong/220 and https://phantom.cs.qc.cuny.edu/kong/220/Slides.

Learning Goals

- To develop mathematical thinking, precise reasoning, and problem-solving abilities, and to gain experience in reading mathematical writing, through the study of selected topics in discrete mathematics that have applications to computer science.
- To understand terminology, methods, arguments, and results of the selected topics.*

*The course exams will test students' understanding of the terminology, methods, arguments, and results covered in the course.


Provisional Syllabus and Schedule†

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<th>Relevant Parts of Rosen</th>
<th>Provisional Syllabus and Schedule†</th>
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<td>vertex- and edge-connectivity; connectedness in digraphs</td>
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†The syllabus and schedule are subject to change.

Homework Assignments

You will be given a set of homework problems for each section of Rosen that is covered in class or in assigned reading. Solutions to the homework problems will be available. *Some exam questions or parts of questions will be of a similar nature to homework problems,* but may possibly be posed as multiple-choice or multiple-response items. Students who have difficulty in solving any homework problem should consult me during my office hours (which are shown above). You will be asked to submit scanned copies or photos of handwritten solutions to certain sets of homework problems, but you should not assume that the problems for which you are asked to submit solutions are more important than other homework problems!

Assignment of course grades below A– will be based mainly on exam scores, but those grades will be determined using rules that also take homework submissions into account. Assignment of A–, A, and A+ grades will be based solely on exam scores. For details of how grades will be determined, see the "Grading Policy" section below.

Class Dates

This class is scheduled to meet on Mondays and Wednesdays from Monday, 8/28 through Monday, 12/11, with the exceptions of the following four dates (when the class is not scheduled to meet): 9/04, 9/25, 10/09, and 11/22. We will also meet on Tuesday, 10/10 (when CUNY classes will follow a Monday schedule), and will meet for a cumulative Final Exam during the Final Exam period. The last day to drop with a grade of W is Monday, 12/11.
Exams

There will be three exams. The maximum possible scores on these exams are shown below:

- **Exam 1** (75 minutes): 25 pts. Tentative date: Monday, November 6
- **Exam 2** (75 minutes): 25 pts. Probable date: Monday, December 11
- **Cumulative Final Exam** (120 minutes): 40 pts. Currently scheduled date & time: Monday, December 18, 8:30 – 10:30 pm

You may bring a "crib" to each of these exams and refer to it during the exam; but your crib must be no larger than a letter size (8.5" × 11") sheet of paper, and for exams 1 and 2 one side of the crib must be blank. (For the final exam your crib may have writing on both sides.) Cribs will be collected at the end of each exam and will not be returned to you. The exams will otherwise be closed book.

**Any change in the date of an exam will be announced at least one week before the new date.**

**Each exam will be given in our regular classroom unless a room change is announced.**

Students who are found to have provided their answers to others during an exam or to have submitted someone else's work as their own will receive an F for the course.

Grading Policy

Your grade will be based on your exam scores and, for grades below A–, credit you earn for submitted homework.

When I compute your grade I will replace the lower of your scores on the first and the second exams with your **Final Exam score × 25/40** if that is higher. (If your scores on the first and the second exams are equal, at most one of those two scores can be replaced in this way.) **There will be no make-ups for the first and second exams.**

Missing either exam will be equivalent to scoring 0, but the 0 will be replaced by (your **Final Exam score × 25/40**) if you miss just one exam. In the sequel, **total exam score** means the sum of the three exam scores after the lower of the scores on the first two exams is replaced with your **Final Exam score × 25/40** if that is higher.

You will be an **A-range student** if the following are both true:

1. You have a higher Final Exam score than at least 70% of the students in the class
2. (your **total exam score × 100/90**) is ≥ the threshold score for A–.

If you are an A-range student who has a higher Final Exam score than at least two-thirds of the A-range students and, in addition, (your **total exam score × 100/90**) is ≥ the threshold score for A+, then your grade for the course will be A+. If you are an A-range student and the previous sentence does not apply to you, your grade will be A– or A according to whether (your **total exam score × 100/90**) is < or ≥ the threshold score for A. Provisional threshold scores for A-range grades are: A+ 97, A 90, A– 87 for CSCI 220 students, and A+ 97, A 91, A– 88 for CSCI 620 students.

If you are not an A-range student, then you will be awarded credit for submitted homework. (Whereas the maximum total score on the exams is 25+25+40 = 90 pts., the maximum total credit for homework is 10 pts.) Let

\[ m = \max(\text{your total exam score} \times 100/90, \text{your total exam score} + \text{credit you earned for homework submissions}) \]

Then your grade will be F if either of the following is true:

(i) You are a graduate student, or you are an undergraduate who has asked to be excluded from consideration for D+ and D grades, and \( m \) is < the threshold score for C.

(ii) You are an undergraduate who has not asked to be excluded from consideration for D+ and D grades,* and \( m \) is < the threshold score for D.

If you are not an A-range student and neither (i) nor (ii) is true, then you will receive the highest grade below A– for which \( m \) is ≥ that grade's threshold score. For CSCI 220 students, provisional threshold scores for grades below A– are: B+ 83, B 80, B– 77, C+ 73, C 69, and, for undergraduates who are being considered for D+ and D grades,* D+ 66, D 60. For CSCI 620 students, provisional threshold scores for grades below A– are: B+ 84, B 81, B– 78, C+ 74, C 70. The threshold for C may be lowered by up to 1 point for some students, at the instructor's discretion. **No grades of C– will be given.**

Students who are absent both from Exam 2 and from the Final Exam may possibly be given a WU.

*Undergraduates in this course will be asked in December to say whether they wish to be considered for D+ and D grades in the event that they do not qualify for a course grade of C or better.
Students will be expected to submit copies of handwritten solutions to the sets of exercises on this page. Full instructions for submission of each set of exercises will be provided to you before its due date.

**Important:** Homework exercises relating to Major Reading Assignments 1 – 3 are given on pages 4 – 5, and other homework will be e-mailed to your euclid account during the semester. Although you will not be asked to submit solutions to those homework exercises, you should **not** assume that they are any less important than the exercises in the sets of homework exercises below.

**Homework Exercises 1**

**Due date:** Thursday, October 5

(a) Do exercises 1*, 3**, 4, 5**, 6, 7***, 8, 9**, 13, and 23 from sec. 10.1 of Rosen (8th ed., pp. 682 – 4).

*The book's solutions to this problem are incomplete: They don't say which of the 6 types of graph from Table 1 is used in each case. The types are: 1(a) simple graph; 1(b) multigraph; 1(c) pseudograph; 1(d) simple directed graph; 1(e) directed multigraph. For drawings of other examples of these types of graph, see Fig. 1 on p. 674 (a simple graph), Fig. 2 on p. 674 (a multigraph), Fig. 3 on p. 674 (a pseudograph), Fig. 4 on p. 675 (a simple directed graph), and Fig. 5 on p. 675 (a directed multigraph).

(b) Do exercises 1, 3, 5, 7, 9, 11†, 19††, 38, 43, 44§, 49, 54, 57§§, 64§§, and 65§§ from sec. 10.2 of Rosen (8th ed., pp. 699 – 702). Also do exercise 45 on p. 776; you **don't** need to know what \( \kappa(G) \) and \( \lambda(G) \) mean to do this exercise!

†An edge is missing from the book's solution to this problem!

††You are not required to do exercise 18, but you may assume the result stated in that exercise is correct.

§In these two questions, “draw a graph” should read “draw a **simple** graph”.

§§Regular graphs are defined before exercise 55. The graph \( G \) is defined in exercise 61; even though Rosen does not state this explicitly, you need to know that \( G \) is a **simple** graph.

**Homework Exercises 2**

**Due date will be announced later.**

(a) Do exercises 21, 22, 23, 24, 25, 26, 27¶, 28, 29, 30, 35‡, 37, 39, 41, 50, 51, 52, 53, 55, 56, 59, 61‡‡, 62‡‡, and 63‡‡ from sec. 10.2 of Rosen (8th ed., pp. 700 – 2). ‣ Edge \{P, h\} is missing from the book's solution to part (a)!

*In the solution to part b, \( f \) should be corrected to \( d, e \). ‡‡‡You need to know that \( \overline{G} \) is a **simple** graph.

(b) Do exercises 1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 29, 31, 32, 33, 34, and 35 from sec. 10.3 of Rosen (8th ed., pp. 710 – 1).

**Homework Exercises 3**

**Due date will be announced later.**

(a) Do exercises 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 51, 52, 53, 55, 57, 59, 63, 64, 73, and 77 from sec. 10.3 of Rosen (8th ed., pp. 711– 4). Also do exercise 31 on p. 775.

(b) Do exercises 1, 2, 3, 4, 5, 6, 31, 32, 33, 34, 39, and 47 from sec. 10.4 of Rosen (8th ed., pp. 724 – 7). In exercise 47, you are only required to do parts a – c.

(c) Do exercises 19, 24, 25, 26, and 27 from sec. 10.4 of Rosen (8th ed., p. 726). For exercise 26, you are only required to do parts a – d. These five exercises relate to the "Counting Paths Between Vertices" subsection (pp. 723 – 4).

**Homework Exercises 4**

**Due date will be announced later.**

(a) Do exercises 11, 12, 14, 15, 50, 53, and 54 from sec. 10.4 of Rosen (8th ed., pp. 725 and 727). Also do exercises 35, 36, and 37 on p. 776.

(b) Do exercises 1, 3, 5, 7, 9, 10, 11, 13, 14, 15, 26, 27, 28, and 29 from sec. 10.5 of Rosen (8th ed., pp. 739 – 40).

(c) Do exercises 30, 31, 32, 33, 34, 35, 37, 39, 40, 41, 43, 44, 45, 47, 48, 55, 57, 59, 60, 61, 62, and 63 from sec. 10.5 of Rosen (8th ed., pp. 740 – 2). Also do exercise 49 on p. 776.

Solutions to odd-numbered exercises are given in Rosen. However, Rosen's solutions to certain exercises are incomplete. The file [https://phantom.cs.qc.cuny.edu/kong/220/Solutions.pdf](https://phantom.cs.qc.cuny.edu/kong/220/Solutions.pdf) gives solutions to the even-numbered exercises above and more complete solutions to some odd-numbered exercises. Work each exercise yourself **before** you look at the solution in Rosen or in the above-mentioned file. If you discover that some of your solutions are wrong, you may make corrections before you submit.

**Late submission policy / penalty:** If you are not an A-range student, then the total credit you receive for submitting homework will be reduced by 1 point if your solutions to three of the four sets of exercises are submitted late, and reduced by 2 points if your solutions to all four sets of exercises are submitted late. (If your solutions to just one or just two sets of exercises are submitted late, you will not be penalized.) The deadline for **late** submission of solutions to the homework exercises is **Friday, December 22.**
**Major Reading Assignment 1 (for the Final Exam)**

In the “Growth of Functions” section (Sec. 3.2) of Rosen, read subsections 3.2.1 – 3.2.4. This topic is sometimes called *infinite asymptotics*.

There will be no questions on this material on Exams 1 and 2. If this topic is not covered in class, then there will be *one* Final Exam question on this material. If this topic is covered in class, then there may be more than one Final Exam question on this topic. The Final Exam question(s) on this topic will consist of one or more parts; each part will be at least fairly similar in nature to part or all of one of the homework exercises that are listed below (but may possibly be formulated as a multiple-choice question). You will not be asked to write proofs relating to this topic, nor to calculate witnesses $C$ and $k$ that establish a big-$O$ relationship.

**Homework:** pp. 228 – 9: Exercises 1, 2, 7, 8, 14, 15, 19, 20, 21, 22, 23, 24, 25, 26, 27

**Solutions to Exercises 2, 8, 14, 20, 22, 24, and 26**

2.(a) Yes (b) Yes (c) Yes (d) No (e) No  (f) Yes
8.(a) 4  (b) 5  (c) 0  (d) –1
14.(a) No (b) Yes (c) Yes (d) Yes (e) Yes (f) Yes
20. Yes, in both cases.
22. function 3, function 4, function 7, function 2, function 1, function 5, function 6
24. The first algorithm uses fewer operations for all sufficiently large values of $n$.
26.(a) $O(n^3 \log n)$  (b) $O(6^n)$  (c) $O(n! n^n)$

**Major Reading Assignment 2 (for the Final Exam)**

In the “Recursive Definitions and Structural Induction” section (Sec. 5.3) of Rosen, read pp. 365 – 8 (up to and including Example 4), and also read subsection 5.3.3 (Recursively Defined Sets and Structures).

There will be no questions on this material on Exams 1 and 2. If this topic is not covered in class, then there will be *one* Final Exam question on this material. If this topic is covered in class, then there may be more than one Final Exam question on this topic. The Final Exam question(s) on this topic will consist of one or more parts; each part will be at least fairly similar in nature to part or all of one of the homework exercises that are listed below (but may possibly be formulated as a multiple-choice question). You will not be asked to write proofs relating to this topic.

**Homework:** pp. 378 – 80: Exercises 1, 3, 7, 9, 11, 23, 24, 25, 33, 35a, 37, 39, 41

**Solution to Exercise 24:**

(a) Basis step: $1 \in S$  
Recursive step: If $n \in S$, then $n + 2 \in S$.
(b) Basis step: $3 \in S$  
Recursive step: If $n \in S$, then $3n \in S$.
(c) Basis step: $0 \in S$  
Recursive step: If $p(x) \in S$, then $p(x) + 1 \in S$, $p(x) – 1 \in S$, and $xp(x) \in S$. 
**Major Reading Assignment 3 (for the Final Exam)**

In the “Sequences and Summations” section (Sec. 2.4) of Rosen, read subsection 2.4.3 (Recurrence Relations). Then read subsections 8.1.1 and 8.1.2 of the “Applications of Recurrence Relations” section (Sec. 8.1).

There will be no questions on this material on Exams 1 and 2. If this topic is not covered in class, then there will be one Final Exam question on this material. If this topic is covered in class, then there may be more than one Final Exam question on this topic. The Final Exam question(s) on this topic will consist of one or more parts; each part will be at least fairly similar in nature to part or all of one of the homework exercises that are listed below (but may possibly be formulated as a multiple-choice question).

**Homework:** pp. 177 – 8: Exercises 9, 11, 13, 15, 17, 18, 19, 20, 21, 23
pp. 536 – 7: Exercises 2, 3, 7, 8, 9, 11, 12, 13, 14

**Solutions to Exercises 18 and 20 on p. 178 and Exercises 2, 8, 12, and 14 on pp. 536–7:**
- p. 178: 18.(a) $a_n = 1.09 \times a_{n-1}$  
(b) $a_n = $1000 $\times 1.09^n$  
(c) $a_{100} = $1000 $\times 1.09^{100}$ [ $\approx $5,529,040.79 ]
- 20.(a) $a_n = 1.0112 \times a_{n-1}$  
(b) $7.6 \times 10^9 \times 1.0112^n$  
(c) $7.6 \times 10^9 \times 1.0112^{33}$ [ $\approx $11.0 billion ]
- p. 536: 2(a) $a_n = na_{n-1}$  
(b) $a_0 = 1$, so $a_n = na_{n-1} = n(n-1)a_{n-2} = n(n-1)(n-2)a_{n-3} = n(n-1)(n-2)...1$ $a_0 = n$
- p. 537: 8(a) $a_n = a_{n-1} + a_{n-2} + a_{n-3} + 2^{n-3}$ for all $n \geq 3$  
(b) $a_0 = a_1 = a_2 = 0$  
(c) $a_7 = 47$
- 12(a) $a_n = a_{n-1} + a_{n-2} + a_{n-3}$ for all $n \geq 3$  
(b) $a_0 = a_1 = 1$, $a_2 = 2$  
(c) $a_8 = 81$
- 14(a) $a_n = 2a_{n-1} + 2a_{n-2} + 3^{n-2}$ for all $n \geq 2$  
(b) $a_0 = a_1 = 0$  
(c) $a_6 = 281$
Accounts on mars (mars.cs.qc.cuny.edu or 149.4.211.180)

You have a Linux account on the machine mars (which is also called venus), and another account on the machine euclid.

Your mars / venus username is as follows:

- first 2 letters of your last name (in lowercase) followed by
- first 2 letters of your first name (in lowercase) followed by
- last 4 digits of your 8-digit CUNYfirst ID.

Example: Washington, George  CUNYfirst ID: 12345678
Username: wage5678

If you have used this account before (in another course), then your password is probably the same as it was when you last used the account. If you have never used your mars account, then your initial password is your 8-digit CUNYfirst ID#.

Note: Don't confuse your mars and euclid accounts; euclid and mars are two different computers. Your euclid account has a different username from your mars account, and euclid account passwords are unrelated to mars account passwords. All assignments must be submitted on euclid.

You can log on to mars from a PC or a Mac as follows:

- If you are on the QC campus, sign into the qwifi-secured wireless network.
- If you are not on the QC campus, connect to the QC VPN. If you have not already installed the PaloAlto GlobalProtect VPN client on your PC or Mac, then you must install that VPN client to be able to connect to the QC VPN:
  - How to install the VPN client on a Windows PC
  - How to install the VPN client on a Mac
- If you cannot sign into the qwifi-secured wireless network or cannot connect to the QC VPN, then you can ask for help from the Queens College Helpdesk: https://support.qc.cuny.edu. But note the following regarding the VPN:
  1. The GlobalProtect VPN client may not work if your machine is running incompatible antivirus software.
  2. You may need to update the VPN client if it tells you an update is available.
  3. The VPN client may not work if your version of macOS or Windows is older than the versions that are listed at https://support.qc.cuny.edu/support/solutions/articles/15000019085 or https://support.qc.cuny.edu/support/solutions/articles/15000019079.

Logging onto your linux account using Mac

- Open the terminal app from Applications/Utilities folder and type
  ssh your_username@mars.cs.qc.cuny.edu
- Type yes to continue connecting
- Type your password. Nothing will display on your screen when you type your password.
  Press ENTER after you complete your password entry.

Logging onto your linux account using Windows PowerShell

- Click Start menu, type Windows Powershell to launch Windows PowerShe and type
  ssh your_username@mars.cs.qc.cuny.edu
- Type yes to continue connecting
- Type your password. Nothing will display on your screen when you type your password.
  Press ENTER after you complete your password entry.

*These instructions are copied from the CS Department's webpage https://venus.cs.qc.cuny.edu/~xiuyi/. The "Type yes to continue connecting" step applies the first time you use the ssh command on a particular PC or Mac to connect to mars; it doesn't apply if you've previously used the ssh command on the same PC or Mac to connect to mars. (If when you enter the command ssh your_username@mars.cs.qc.cuny.edu you are warned that "REMOTE HOST IDENTIFICATION HAS CHANGED!", then enter the command ssh-keygen -R mars.cs.qc.cuny.edu and try again after that.)

It is important that you be able to log on to mars. Make sure you can do that before our second class meeting: If you can't log on to mars, then email the CS Department's Administrative Coordinator Xiuyi Huang at xiuui.huang@qc.cuny.edu to ask for help. NOTE: This applies only to mars. If you can log on to mars but need help with your euclid account, then see me during one of my office hour periods.

Any time you are logged in to mars, you can login to your euclid account by entering

```
ssh ????_????????@euclid.cs.qc.cuny.edu
```
at mars's ... @mars:~$ prompt; here ????_???????? means your euclid username. If you get a “Host key verification failed.” error, retry after entering the following on mars: ssh-keygen -R euclid.cs.qc.cuny.edu

Your euclid account has a different username and a different initial password from your mars account. Be sure to read the next page before you try to login to your euclid account for the first time!
Accounts on euclid (euclid.cs.qc.cuny.edu or 149.4.211.94)

In addition to your mars account, you have an account on euclid; mars and euclid are different machines. Your euclid account has a different username and a different initial password from your mars account. I plan to e-mail copies of important course-related information to everyone’s euclid account. For this reason, and to reduce the risk of forgetting your euclid password, be sure to check e-mail on euclid at least twice a week—you can do this by entering alpine -i on euclid after you log on.

If you registered for the class before 8/26, your euclid username is xxxxx_yyyy220, where:

- xxxxx = your last name in lowercase if it has ≤ 5 letters (omit any space or hyphen in the name)
- xxxxx = first 5 letters of your last name in lowercase if it has > 5 letters
- yyyy = your first name (as shown on the attendance sheet) in lowercase if it has ≤ 4 letters
- yyy = first 4 letters of your first name in lowercase if it has > 4 letters

Examples:
- David Touretzky -> toure_davi220
- Ada Lovelace -> lovel_ada220
- Ravi Sethi -> sethi_ravi220

Your initial euclid password is q followed by the last 7 digits of your CUNYfirst ID.

Example: If your CUNYfirst ID is 12345678, then q2345678 is your initial password.

The first time you log on, you will be asked to choose a new password, so think of a good password in advance—see, e.g., https://computing.cs.cmu.edu/security/security-password.html.

Assuming you are already logged on to mars, you can log on to euclid by entering

```
ssh ?????_????220@euclid.cs.qc.cuny.edu
```

at mars’s ...

The first time you use ssh on mars to connect to euclid you will be asked if you trust euclid’s “key fingerprint”: Answer yes. You will then be prompted for your euclid password: Enter q followed by the last 7 digits of your CUNYfirst ID. **NOTE: No characters should appear on the screen when you type the password at a "... password:" prompt—the cursor should not move—but the system will know what keys you pressed! Remember to press Enter at the end.

You will have to change your password, but you must first re-enter your q ... password:

```
Changing password for ?????_????220.
```

Do NOT enter your new password at this prompt: Enter q followed by the last 7 digits of your CUNYfirst ID one more time. You will then be prompted for a new password:

```
New password:
```

If you re-enter your new password correctly, your password will be changed and you will be logged off. Immediately log on to euclid again (using your new password!) and then do the following:

1. Enter the command xc on euclid.
2. Enter the command alpine -i on euclid and check that an email with the subject “Automatically Generated Reply” is listed in your alpine message index; also make sure you can read the email. After that, type q and then type y to quit alpine.

If you do 1 and 2 no later than Thursday, September 7**, then you will receive 0.25 pt. extra credit: The threshold score for each letter grade will be lowered by 0.25 pt. (e.g., from 97 to 96.75 for A+) when I compute your grade for the course.

Do not try to send email from your euclid account, and do not ask others to try to send email to your euclid account. Also do not install any software on euclid that you have not been asked to install.

*The first time you log on to your euclid account, please do so by ssh from mars. (After you have verified that you can log on to euclid via mars, you may in future prefer to connect to euclid using an ssh client on your PC or Mac—e.g., follow the Logging onto your linux account using Windows PowerShell instructions or the Logging onto your linux account using Mac instructions on the previous page, but replace mars with euclid in those instructions.

**If you don’t do 1 and 2 by Sep. 7, your account may be deactivated (for security reasons). To reactivate a deactivated account, or to reset a forgotten password, you must see me after class or during an office hour meeting. [Note that I will not reactivate accounts or reset passwords in response to e-mail messages.]