Electrical & Computer ENGINEERING

Carnegie Mellon

Course Syllabus

18-600: "*Foundations of Computer Systems*"

Spring 2018

(finalized)

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Course Description: This course provides both the programmer's and architect's views of how computer systems execute programs, store information, and communicate. It enables students to become more effective programmers, especially in dealing with issues of performance, portability and robustness. It prepares students for follow on courses focusing on compilers, operating systems, computer architecture, and computer networks. Topics covered include: machine-level code and its generation by optimizing compilers, performance evaluation and optimization, computer arithmetic, processor architecture, parallel architecture, memory organization and management, networking technology and protocols, concurrent computation workloads. This course is modeled after 15-213/18-213/15-513, but with additional course content on current state of the art in computer systems. This is a graduate level course designed for ECE MS students. It prepares students for other graduate level computer systems courses as well as for working in the industry. **Anti-requisites**: 15-213/18-213/15-513. **Number of Units: 12 units**. **Pre-requisites:** Programming Experience, preferably in C; Computer Organization Course; Some exposure to Assembly Language Programs, preferably x86, and Computer Architecture.

Class Schedule:

- **Lectures**: (twice weekly on Monday & Wednesday)
  Lectures, Section A:
  MW, 6:30pm to 8:20pm (ET), HH 1107
  Lectures, Section B:
  MW, 6:30pm to 8:20pm (ET), HH 1107

  Lectures, Section SA:
  MW, 3:30pm to 5:20pm (PT), B23 118
  Lectures, Section SB:
  MW, 3:30pm to 5:20pm (PT), B23 118

- **Labs/Recitations**: (once weekly on Tuesday)
  Recitation, Section A:
  T, 4:30pm to 5:50pm (ET), WEH 4709
  Recitation, Section B:
  T, 4:30pm to 5:50pm (ET), GHC 4301

  Recitation, Section SA:
  T, 4:30pm to 5:50pm (PT), B23 211
  Recitation, Section SB:
  T, 4:30pm to 5:50pm (PT), B23 110

Required Textbooks:

1. Randal E. Bryant and David R. O'Hallaron, *Computer Systems: A Programmer's Perspective, Third Edition (CS:APP3e)*, Pearson, 2016.
2. Brian W. Kernighan and Dennis M. Ritchie, *The C Programming Language, Second Edition*, Prentice Hall, 1988.

Recommended References:

1. *Modern Processor Design: Fundamentals of Superscalar Processors,* by John P. Shen and Mikko Lipasti, 2005; reissued by Waveland Press Inc, 2013. ISBN 10: 1-4786-0783-1, ISBN 13: 978-1-4786-0783-0
2. *Parallel Computer Organization and Design,* by Michel Dubois, Murali Annavaram, Per Stenstrom, Cambridge University Press, 2012. ISBN 978-0-521-88675-8.

Course Web Sites:

We will use Piazza in this course for communication: https://piazza.com/cmu/spring2018/18600/home
All 18-600 handout materials will be posted on Canvas at: https://canvas.cmu.edu/courses/3838
Grades for labs and exams will also be made available at: https://canvas.cmu.edu/courses/3838

Tentative Course Calendar (18-600 Spring 2018):

Week	Date	Day	Class Activity	Labs
Week 1	1/15	Mon	NO CLASS - MLK DAY	
	1/16	Tues	NO CLASS - (Recitation starts in Week 2)	
	1/17	Wed	Lecture 1: Course Introduction and Overview [JS/BN]	
Week 2	1/22	Mon	Lecture 2: Big Picture of Computer Systems [JS] (Chapter 1)	
	1/23	Tues	Recitation 1: C & Linux boot camp, Lab 1 Out (Data Lab)	Lab 1 Data
	1/24	Wed	Lecture 3: Information Representation I: Integers [BN] (2)	
Week 3	1/29	Mon	Lecture 4: Information Representation II: Floating Points [BN] (2)	
	1/30	Tues	Recitation 2: Data Lab discussion and help	
	1/31	Wed	Lecture 5: Machine Programs I: Control & Procedures [BN] (3)	
	2/4	Sun	Lab 1 Due (Data Lab); Lab 2 Out (Bomb Lab)	Lab 2 Bomb
Week 4	2/5	Mon	Lecture 6: Machine Programs II: Data & Programs [BN] (3)	
	2/6	Tues	Recitation 3: Bomb Lab overview; GDB overview w/ Attack Lab (opt)	
	2/7	Wed	Lecture 7: Processor Architecture I: Processor Design [JS] (4)	
Week 5	2/12	Mon	Lecture 8: Processor Architecture II: Processor Performance [JS] (4)	
	2/13	Tues	Recitation 4: Gem5 Simulator tutorial & OH time for Bomb Lab help	
	2/14	Wed	Lecture 9: Processor Architecture III: Superscalar Processors [JS] (4)	
	2/18	Sun	Lab 2 Due (Bomb Lab); Lab 3 Out (Arch Lab)	Lab 3 Arch
Week 6	2/19	Mon	Lecture 10: Program Performance Optimizations [JS] (5)	
	2/20	Tues	Recitation 5: Arch Lab overview & discussion	
	2/21	Wed	Lecture 11: Except. Control Flow I: Exceptions & Processes [BN] (8)	
Week 7	2/26	Mon	Lecture 12: Except. Control Flow II: Signals & Nonlocal Jump [BN] (8)	
	2/27	Tues	Recitation 6: Linking & Loading overview (7); OH for Arch Lab help	
	2/28	Wed	Lecture 13: Memory Hierarchy I: Main Memory [JS] (6)	
	3/4	Sun	Lab 3 Due (Arch Lab); Lab 4 Out (Shell Lab)	Lab 4 Shell
Week 8	3/5	Mon	Mock Mid-Term Exam 1	
	3/6	Tues	Recitation 7: Shell Lab overview & discussion	
	3/7	Wed	MID-TERM EXAM 1 (120 min.)	

Week 9	3/12	Mon	NO CLASS - SPRING BREAK	
	3/13	Tues	NO CLASS - SPRING BREAK	
	3/14	Wed	NO CLASS - SPRING BREAK	
Week 10	3/19	Mon	Lecture 14: Memory Hierarchy II: Cache Memories & Storage [JS] (6)	Lab 5 Cache
	3/20	Tues	Lab 4 Due (Shell Lab); Lab 5 Out (Cache Lab)	
	3/20	Tues	Recitation 8: Cache Lab overview	
	3/21	Wed	Lecture 15: Multicore Processors and Cache Coherence [JS] (6)	
Week 11	3/26	Mon	Lecture 16: Virtual Memory I: Concepts and Systems [JS] (9)	
	3/27	*Tues*	Recitation 9: (no recitation) OH for Cache Lab help	
	3/28	Wed	Lecture 17: Virtual Memory II: Dynamic Memory Allocation [BN] (9)	
Week 12	4/2	Mon	Lecture 18: System Level I/O [BN] (10)	Lab 6 Malloc
	4/3	Tues	Lab 5 Due (Cache Lab); Lab 6 Out (Malloc Lab)	
	4/3	Tues	Recitation 10: Malloc Lab overview & discussion	
	4/4	Wed	Lecture 19: Parallel Architectures and Programming [JS]	
Week 13	4/9	Mon	Lecture 20: Network Programming - Part I [BN] (11)	
	4/10	Tues	Recitation 11: Malloc Lab checkpoint; OH time for Malloc Lab help	
	4/11	Wed	Lecture 21: Performance, Power, and Energy of Computers [JS]	
Week 14	4/16	Mon	Lecture 22: Network Programming - Part II [BN] (11)	
	4/17	Tues	Recitation 12: Proxy Lab overview & discussion	
	4/18	Wed	Lecture 23: Concurrent Programming [BN] (12)	Lab 7 Proxy
	4/22	Sun	Lab 6 Due (Malloc Lab); Lab 7 Out (Proxy Lab)	
Week 15	4/23	Mon	Lecture 24: Thread Synchronization [BN] (12)	
	4/24	Tues	Recitation 13: Review for Exam 2 & OH time for Proxy Lab help	
	4/25	Wed	Lecture 25: Future of Computing 1: Convergence & Continuum [JS]	
Week 16	4/30	Mon	Lecture 26: Future of Computing 2: Big Learning & Silicon Brain [JS]	
	5/1	Tues	Recitation 14: Mock Exam 2; OH time for Proxy Lab help	
	5/2	Wed	MID-TERM EXAM 2 (120 min.)	
Week 17	5/9	Tues	Lab 7 Due (Proxy Lab)	

Education Objectives (Relationship of Course to Program Outcomes):

The ECE department is accredited by ABET to ensure the quality of your education. ABET defines 11 Educational Objectives that are fulfilled by the sum total of all the courses you take. The following list describes which objectives are fulfilled by 18-600 and in what manner they are fulfilled. The objectives are lettered from "a" through "k" in the standard ABET parlance. Those objectives not fulfilled by 18-600 have been omitted from the following list.

(a) an ability to apply knowledge of mathematics, science, and engineering: Labs and projects.
(b) an ability to design and conduct experiments, as well as to analyze and interpret data: Labs and projects.
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability: Labs and projects, and special guest lectures by practicing computer architects from industry.
(d) an ability to function on multidisciplinary teams: Work in small teams on labs and projects.
(e) an ability to identify, formulate, and solve engineering problems: Extensive coverage of design tradeoffs.
(g) an ability to communicate effectively: Written reports and in-class presentations.
(i) a recognition of the need for, and an ability to engage in lifelong learning: Historical insights provided during lectures.
(j) a knowledge of contemporary issues: Industry guest lecturers will provide a good sense of these issues.
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice: Labs and project works, and industry guest lecturers.

ECE Academic Integrity Policy (http://www.ece.cmu.edu/programs-admissions/masters/academic-integrity.html**):**

The Department of Electrical and Computer Engineering adheres to the academic integrity policies set forth by Carnegie Mellon University and by the College of Engineering. ECE students should review fully and carefully Carnegie Mellon University's policies regarding Cheating and Plagiarism; Undergraduate Academic Discipline; and Graduate Academic Discipline. ECE graduate student should further review the Penalties for Graduate Student Academic Integrity Violations in CIT outlined in the CIT Policy on Graduate Student Academic Integrity Violations. In addition to the above university and college-level policies, it is ECE's policy that an ECE graduate student may not drop a course in which a disciplinary action is assessed or pending without the course instructor's explicit approval. Further, an ECE course instructor may set his/her own course-specific academic integrity policies that do not conflict with university and college-level policies; course-specific policies should be made available to the students in writing in the first week of class. *This policy applies, in all respects, to this course.*

18-600 COURSE POLICY

Lab Assignments:

You will work on all lab assignments by yourself. All assignments are due at **11:59pm PT** on the **specified due date (usually on a Sunday or Tuesday)**. All hand-ins are done using the **Autolab** system. You may hand in as often as you like, with your most recent hand-in counting for credit.

The penalty for late assignments is **10% per day**. Each student will receive a total budget of **five grace days** for the entire course. Each grace day can be used to cover one day late without incurring the 10% penalty.

- Grace days are applied automatically until you run out. But, no more than two grace days can be used on any one assignment.
- Once you have spent your grace days, or exhausted the grace day limit for an assignment, then you will receive a penalty of 10% for each subsequent late day.
- Late assignments will only be accepted up to three days after the specified due date, or the **termination date**, i.e. all late submissions must be submitted by the termination date and can only be late by up to three days.

Grading Algorithm:

50%	Lab Assignments (7)
25%	Midterm Exam 1
25%	Midterm Exam 2
100%	TOTAL

Final Grade Assignment:

Each student will receive a numeric score for the course, based on a weighted sum of the following:

- Lab Assignments (50%): There are a total of seven lab assignments, which will count a combined total of 50% of your course score. Assignments have different weightings, based on the relative efforts required. See the class Web page for the assignment weightings.
- Exams (50%): There will be two midterm exams counting 25% each.

Final Letter Grades for the course will be determined by the total of lab assignments and the exams with their weightings. A class curve will be set based on the distribution of the total scores. Historically, the class average of the total scores has been around 75%-80% with a B+ curve for the entire class, i.e. average of letter grades in the 3.2-3.4 range. Individual cases, especially those near the cutoff points, may be adjusted upward or downward (by up to 5%) based on factors such as attendance, class participation (including contributions during lectures and recitations, and on Piazza), improvement throughout the course, and special circumstances.

CMU Academic Integrity Policy (http://www.cmu.edu/academic-integrity/index.html):

In the midst of self exploration, the high demands of a challenging academic environment can create situations where some students have difficulty exercising good judgment. Academic challenges can provide many opportunities for high standards to evolve if students actively reflect on these challenges and if the community supports discussions to aid in this process. It is the responsibility of the entire community to establish and maintain the integrity of our university.

This site is offered as a comprehensive and accessible resource compiling and organizing the multitude of information pertaining to academic integrity that is available from across the university. These pages include practical information concerning policies, protocols and best practices as well as articulations of the institutional values from which the policies and protocols grew. The Carnegie Mellon Code, while not formally an honor code, serves as the foundation of these values and frames the expectations of our community with regard to personal integrity.

The Carnegie Mellon Code

Students at Carnegie Mellon, because they are members of an academic community dedicated to the achievement of excellence, are expected to meet the highest standards of personal, ethical and moral conduct possible.

These standards require personal integrity, a commitment to honesty without compromise, as well as truth without equivocation and a willingness to place the good of the community above the good of the self. Obligations once undertaken must be met, commitments kept.

As members of the Carnegie Mellon community, individuals are expected to uphold the standards of the community in addition to holding others accountable for said standards. It is rare that the life of a student in an academic community can be so private that it will not affect the community as a whole or that the above standards do not apply.

The discovery, advancement and communication of knowledge are not possible without a commitment to these standards. Creativity cannot exist without acknowledgment of the creativity of others. New knowledge cannot be developed without credit for prior knowledge. Without the ability to trust that these principles will be observed, an academic community cannot exist.

The commitment of its faculty, staff and students to these standards contributes to the high respect in which the Carnegie Mellon degree is held. Students must not destroy that respect by their failure to meet these standards. Students who cannot meet them should voluntarily withdraw from the university.
This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Cheating (http://www.cmu.edu/academic-integrity/cheating/index.html) states the following:

According to the University Policy on Academic Integrity, cheating "occurs when a student avails her/himself of an unfair or disallowed advantage which includes but is not limited to:

- Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
- Use of an alternate, stand-in or proxy during an examination.
- Copying from the examination or work of another person or source.
- Submission or use of falsified data.
- Using false statements to obtain additional time or other accommodation.
- Falsification of academic credentials."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Plagiarism (http://www.cmu.edu/academic-integrity/plagiarism/index.html) states the following:

According to the University Policy on Academic Integrity, plagiarism "is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to:

- Text, either written or spoken, quoted directly or paraphrased.
- Graphic elements.
- Passages of music, existing either as sound or as notation.
- Mathematical proofs.
- Scientific data.
- Concepts or material derived from the work, published or unpublished, of another person."

This policy applies, in all respects, to this course.

Carnegie Mellon University's Policy on Unauthorized Assistance
(http://www.cmu.edu/academic-integrity/collaboration/index.html) states the following:

According to the University Policy on Academic Integrity, unauthorized assistance "refers to the use of sources of support that have not been specifically authorized in this policy statement or by the course instructor(s) in the completion of academic work

to be graded. Such sources of support may include but are not limited to advice or help provided by another individual, published or unpublished written sources, and electronic sources. Examples of unauthorized assistance include but are not limited to:

- Collaboration on any assignment beyond the standards authorized by this policy statement and the course instructor(s).
- Submission of work completed or edited in whole or in part by another person.
- Supplying or communicating unauthorized information or materials, including graded work and answer keys from previous course offerings, in any way to another student.
- Use of unauthorized information or materials, including graded work and answer keys from previous course offerings.
- Use of unauthorized devices.
- Submission for credit of previously completed graded work in a second course without first obtaining permission from the instructor(s) of the second course. In the case of concurrent courses, permission to submit the same work for credit in two courses must be obtained from the instructors of both courses."

This policy applies, in all respects, to this course.

CMU Experience – Health and Well Being

Take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus and an important part of the college experience is learning how to ask for help. Asking for support sooner rather than later is often helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at http://www.cmu.edu/counseling/. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

- For Pittsburgh students: Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922and visit their website.
- For SV students: For local help and referrals, please contact the Director of Student Affairs at 650-335-2846, Building 19, Room 1041 or email student-services@sv.cmu.edu. Counseling and Psychological Services (CaPS) at the Pittsburgh campus can also help you get connected to support: call 412-268-2922and visit their website to learn more.

If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

CaPS: 412-268-2922
Re:solve Crisis Network: 888-796-8226
If the situation is life threatening, call the police:
On campus: 650-604-5555
Off campus: 911

If you have questions about this or your coursework, please let me know.