Electrical & Computer ENGINEERING

Carnegie Mellon

# Course Syllabus

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

**Fall 2017**

**(2017/09/15)**


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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 also serves as a foundation for courses on compilers, operating systems, computer architecture, and networking, where a deeper understanding of systems-level issues is required. 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, and supporting concurrent computation workloads. This course is modeled after 15-213/18-213/15-513, and is intended for ECE and INI MS students with expanded course contents presented at the graduate level. It prepares students for other graduate level computer systems courses as well as 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; Exposure to Assembly Language Programs, preferably x86; Exposure to Computer Architecture would be a nice plus.

**Class Schedule:**

- **Lecture**:
  *Lectures, Section A:*
  *MW, 6:30pm to 8:20pm (ET), DH A302*
  *Lectures, Section B:*
  *MW, 6:30pm to 8:20pm (ET), DH A302*
  *Lectures, Section C:*
  *MW, 6:30pm to 8:20pm (ET), DH A302*
  *Lectures, Section D:*
  *MW, 6:30pm to 8:20pm (ET), DH A302*
  *Lectures, Section SA:*
  *MW, 3:30pm to 5:20pm (PT), B23 118*
  *Lectures, Section SB:*
  *MW, 3:30pm to 5:20pm (PT), B23 211*

- **Labs/Recitation**:
  *Recitation, Section A:*
  *T, 7:30pm to 8:50pm (ET), HH 1107*
  *Recitation, Section B:*
  *T, 7:30pm to 8:50pm (ET), GHC 4102*
  *Recitation, Section C:*
  *T, 5:30pm to 6:50pm (ET), WEH 4623*
  *Recitation, Section D:*
  *T, 5:30pm to 6:50pm (ET), WEH 4623*
  *Recitation, Section SA:*
  *T, 4:30pm to 5:50pm (PT), B23 118*
  *Recitation, Section SB:*
  *T, 4:30pm to 5:50pm (PT), B23 109/110*

**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/fall2017/18600/home
All 18-600 handout materials can be found at: https://ece.cmu.edu/~ece600/
Grades for labs and exams would be made available at: https://canvas.cmu.edu/courses/1270

**Grading Algorithm:**

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|---|---|
| 50% | Lab assignments (7) |
| 20% | Midterm exam |
| 30% | Final exam |
| 100% | TOTAL |

**Tentative Course Calendar (18-600 Fall 2017)**

| Week | Date | Day | Class Activity | Labs |
|---|---|---|---|---|
| **August/September** | | | | |
| Week 1 | 8/28 | Mon | **Lecture 1: Course Introduction & Overview** [JS] | |
| | 8/29 | Tues | Recitation 1: Course Tips, C/Linux overview | |
| | 8/30 | Wed | **Lecture 2: Big Picture of Computer Systems** [JS]<br>**8/31 (Thur): Lab 1 Out (Data Lab) C/Linux boot camp during OH** | |
| Week 2 | 9/4 | Mon | NO CLASS - LABOR DAY HOLIDAY | |
| | 9/5 | Tues | Recitation 2: Data Lab overview (hands-on setup time) | |
| | 9/6 | Wed | **Lecture 3: Information Representation I: Integers** [GK] | Lab 1 Data |
| Week 3 | 9/11 | Mon | **Lecture 4: Information Representation II: Floating Points** [GK] | |
| | 9/12 | Tues | Recitation 3: GDB overview & OH time for Data Lab help | |
| | 9/13 | Wed | **Lecture 5: Machine Programs I: Control & Procedures** [GK]<br>**9/14 (Thur): Lab 1 Due (Data Lab); Lab 2 Out (Bomb Lab)** | |
| Week 4 | 9/18 | Mon | **Lecture 6: Machine Programs II: Data & Programs** [GK] | |
| | 9/19 | Tues. | Recitation 4: Bomb Lab overview; Walk through Attack Lab (optional) | |
| | 9/20 | Wed. | **Lecture 7: Processor Architecture I: Processor Design** [JS] | Lab 2 Bomb |
| Week 5 | 9/25 | Mon | **Lecture 8: Processor Architecture II: Pipelined Processors** [JS] | |
| | 9/26 | Tues | Recitation 5: Gem5 Simulator tutorial & OH time for Bomb Lab help | |
| | 9/27 | Wed | **Lecture 9: Processor Architecture III: Superscalar O3 Processors** [JS]<br>**9/28 (Thur): Lab 2 Due (Bomb Lab); Lab 3 Out (Arch Lab)** | |
| **October** | | | | |
| Week 6 | 10/2 | Mon | **Lecture 10: Memory Hierarchy** [JS] | |
| | 10/3 | Tues | Recitation 6: Arch Lab overview & discussion | |
| | 10/4 | Wed | **Lecture 11: Cache Memories** [JS] | Lab 3 Arch |
| Week 7 | 10/9 | Mon | **Lecture 12: Exceptional Control Flow I: Exceptions & Processes** [GK] | |
| | 10/10 | Tues | Recitation 7: Shell Lab overview & OH time for Arch Lab help | |
| | 10/11 | Wed | **Lecture 13: Exceptional Control Flow II: Signals & Nonlocal Jumps** [GK]<br>**10/12 (Thur): Lab 3 Due (Arch Lab); Lab 4 Out (Shell Lab)** | |

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| Week 8 | 10/16 | Mon | **Lecture 14: System Level I/O** [GK] | Lab 4 Shell |
| | 10/17 | Tues | Recitation 8: Linking & Loading overview; Shell Lab overview & discussion | |
| | 10/18 | Wed | **Lecture 15: Virtual Memory Concepts & Systems** [GK] | |
| Week 9 | 10/23 | Mon | **Lecture 16: Dynamic Memory Allocation** [GK] | |
| | 10/24 | Tues | Recitation 9: Review for Mid-Term Exam & OH time for Shell Lab help | |
| | 10/25 | Wed | **Lecture 17: Cache Coherence in Multicore Processors** [JS]<br>**10/26 (Thur): Lab 4 Due (Shell Lab); Lab 5 Out (Cache Lab)** | |
| **November** | | | | |
| Week 10 | 10/30 | Mon | **MID-TERM EXAM (110 min.)** | Lab 5 Cache |
| | 10/31 | Tues | Recitation 10: Cache Lab overview & discussion; form teams of two (optional) | |
| | 11/1 | Wed | **Lecture 18: Program Performance Optimizations** [JS] | |
| Week 11 | 11/6 | Mon | **Lecture 19: Virtual Machine Design** [JS] | |
| | 11/7 | Tues | Recitation 11: Malloc Lab overview; OH time for Cache Lab help | |
| | 11/8 | Wed | **Lecture 20: Parallel Architecture Systems** [JS]<br>**11/9 (Thur) Lab 5 Due (Cache Lab); Lab 6 Out (Malloc Lab)** | |
| Week 12 | 11/13 | Mon | **Lecture 21: Network Programming I:** [GK] | Lab 6 Malloc |
| | 11/14 | Tues | Recitation 12: Malloc Lab checkpoint; OH time for Malloc Lab help | |
| | 11/15 | Wed | **Lecture 22: Network Programming II:** [GK] | |
| Week 13 | 11/20 | Mon | **Lecture 23: Network Programming III:** [GK] | |
| | 11/21 | Tues | NO CLASS - THANKSGIVING | |
| | 11/22 | Wed | NO CLASS - THANKSGIVING<br>**11/24 (Fri) Lab 6 Due (Malloc Lab); Lab 7 Out (Proxy Lab)** | |
| Week 14 | 11/27 | Mon | **Lecture 24: Concurrent Programming I:** [GK] | Lab 7 Proxy |
| | 11/28 | Tues | Recitation 13: Proxy Lab overview & discussion | |
| | 11/29 | Wed | **Lecture 25: Concurrent Programming II:** [GK] | |
| **December** | | | | |
| Week 15 | 12/4 | Mon | **Lecture 26: Performance & Power Iron Laws** [JS] | |
| | 12/5 | Tues | Recitation 14: Review for Final Exam & OH time for Proxy Lab help | |
| | 12/6 | Wed | **Lecture 27: Future of Computing Systems** [JS]<br>**12/8 (Fri) Lab 7 Due (Proxy Lab)** | |
| Week 16 | | | | |
| | **12/14?** | **Thur** | **FINAL EXAM (180 min.)** | |

**Education Objectives (Relationship of Course to Program Outcomes)**:
(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.
(f) an understanding of professional and ethical responsibility:
(g) an ability to communicate effectively: Written reports and in-class presentations.
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context:
(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**. 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. each late assignment can only be late by up to three days.

**Final Grade Assignment:**

Each student will receive a numeric score for the course, based on a weighted average 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 a midterm exam counting 20% and a final exam counting 30%.

Grades for the course will be determined by a method that combines both a small amount of curving and absolute standards. The total score will be plotted as a histogram. Cutoff points are determined by examining the quality of work by students on the borderlines. 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.

***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 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. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help. Counseling and Psychological Services (CaPS) at the Pittsburgh campus can help you: call 412-268-2922 or visit their website http://www.cmu.edu/counseling/. For SV campus, please contact the Director of Student Affairs at 650-335-2846, Building 19, Room 1041 or student-services@sv.cmu.edu.*

**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.*

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

According to the University Policy For Handling Alleged Misconduct In Research, “Carnegie Mellon University is responsible for the integrity of research conducted at the university. As a community of scholars, in which truth and integrity are fundamental, the university must establish procedures for the investigation of allegations of misconduct of research with due care to protect the rights of those accused, those making the allegations, and the university. Furthermore, federal regulations require the university to have explicit procedures for addressing incidents in which there are allegations of misconduct in research.”

The policy goes on to note that “misconduct means:

- fabrication, falsification, plagiarism, or other serious deviation from accepted practices in proposing, carrying out, or reporting results from research;

- material failure to comply with Federal requirements for the protection of researchers, human subjects, or the public or for ensuring the welfare of laboratory animals; or

- failure to meet other material legal requirements governing research."

"To be deemed misconduct for the purposes of this policy, a 'material failure to comply with Federal requirements' or a 'failure to meet other material legal requirements' must be intentional or grossly negligent."

To become familiar with the expectations around the responsible conduct of research, please review the guidelines for Research Ethics published by the Office of Research Integrity and Compliance.

*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.