

Graduate Study Manual 2018-2019

Electrical Engineering &
Computer Science Department

* Effective Fall 2018 - Summer 2019

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Welcome

As the Director of Graduate Studies (DGS) of the Department of Electrical Engineering and Computer Science (EECS) in Northwestern University's McCormick School of Engineering and Applied Science, it gives me great pleasure to welcome you. I wish you very successful and pleasant years at Northwestern University.

Sincerely,

Randy Freeman, Professor
Director of Graduate Studies
EECS Department
Email: freeman@eecs.northwestern.edu

1. Overview

This manual provides detailed information about the educational opportunities in our graduate programs in electrical engineering, computer engineering, and computer science. It includes descriptions of our curricula, suggestions for coursework, and information about our faculty, computer facilities, and student activities.

The document is in full compliance with the guidelines provided by The Graduate School (TGS) and often refers to sources available through their website.

1.1 General Notes

In addition to the world-class educational opportunities to work with top faculty while accessing a wealth of facilities, research labs, and libraries for intellectual growth, Northwestern University offers a variety of services which can assist you in different aspects of student life.

Wildcard:

The Wildcard is your photo identification card and can be used in almost every place that requires identity verification on campus (library, recreational facilities, Norris University Center, intercampus bus transit, etc.). It is issued by the Wildcard office in Norris University Center, underground level, Evanston campus, and at the University Services (support services) office in Abbott Hall, Room 100, Chicago campus. Lost or stolen ID cards are replaced for a \$15 fee. Broken or damaged cards will be replaced at no charge (providing the damaged card is returned). <https://www.northwestern.edu/wildcard/>

Transportation:

There are three basic types of transportation available:

- There are several shuttle buses that operate on the Chicago and Evanston campuses (and between the two) upon presentation of a Wildcard. Detailed information is available at: <http://www.northwestern.edu/uservices/transportation/shuttles/>
- The Route 201 Chicago Transit Authority (CTA) bus offers free service to Ryan field and to the Old Orchard mall in Skokie upon presentation of a Wildcard.
- U-Pass is a collaboration between Northwestern and CTA based on fare cards called [Ventra](#) – a contactless payment system serves as your U-Pass. The card is issued at the beginning of every academic year, and it can be used 365 days a year on all CTA vehicles.

Health Services:

Northwestern University provides basic outpatient care and other primary-care services, and there are facilities on both the Evanston and Chicago campuses. The Evanston location is at 633 Emerson Street (Searle Building) <https://www.northwestern.edu/healthservice-evanston/>.

Per TGS regulations, every graduate student is legally required to have health insurance coverage. While it is provided for PhD students and partial coverage is available for MS students, one may opt out of this coverage, as long as there is proof of alternate coverage for the entire duration of graduate studies.

Student Affairs:

The Division of Student Affairs (<https://www.northwestern.edu/studentaffairs> -- see 'Departments' tab at top of page) offers many diverse community-building activities, helpful organizations and professional support services to enrich student life. Staff and services at Norris Center (<https://www.northwestern.edu/norris/index.html> -- see 'Services' tab at top of page) can help address any and all personal concerns with dignity and respect.

Counseling and Psychological Services (CAPS): (847-491-2151)

CAPS provides a set of core mental health services on campus, including clinical services, educational workshops, and consultation with faculty and staff as needed. Services are free for all students and available on both the Evanston (633 Emerson St) and Chicago campuses (Abbott Hall, 5th Floor, Suite 500, #710 N. Lake Shore Drive) <http://www.northwestern.edu/counseling>

Personal Safety:

You should always be aware of your surroundings and avoid areas that have indication of being a potentially non-safe environment (e.g., poorly lit walkways and alleys at night). **In the case of emergency, always dial 911.** All the blue-light poles distributed across the University hold phones for immediate contact with University police. For non-emergency matters call 847-491-3456. The University Police are on duty 24 hours a day, 7 days a week and they are located at 1200 Davis St. in Evanston.

International Office (IO):

The IO is available to all the international students and its primary two roles are: (a) to provide guidance/advise for maintaining proper immigration status consistent with the laws of the United States; (b) to ensure compliance with those laws and help the students with various forms, such as OPT (Optional Practical Training) and CPT (Curriculum Practical Training). The IO is located at 630 Dartmouth place and the regular hours of operations are M-F, 10AM-5PM. <https://www.northwestern.edu/international>

The Graduate School (TGS) – other resources and information:

Every graduate student is assigned a counselor at TGS. The counselor monitors overall academic progress from the standpoint of TGS-based milestones, along with satisfactory GPA, etc. Please be advised that most of the forms that concern completion of milestones are subject to a final approval by TGS in addition to being approved by your academic advisor and/or the EECS department.

TGS is located at 633 Clark Street in Evanston, and its webpage www.tgs.northwestern.edu contains a wealth of information pertaining to various aspects of student life.

EECS Departmental Resources:

Graduate students are expected to discuss all academic issues with their advisors first in an open and constructive manner. Further help with administrative aspects is provided by the EECS Graduate Student Affairs Office (Tech, Room L-351 – eecsgrad@northwestern.edu). The staff in the Graduate Office is experienced and can advise you on the course of action and promptly take the measures needed towards achieving a particular goal towards successful completion of your degree. Mailboxes maintained by the staff are provided for all graduate students for university-related postal-mail and packages only (not for personal use), and are located in the EECS Graduate Student Affairs Office. Each student is expected to show their Wildcard upon pickup, and may only pick up their own mail, not that of another student. It should be made a matter of a habit to check for such mail at least once a month. Our mailing address is:

Department of Electrical Engineering and Computer Science
McCormick School of Engineering
2145 Sheridan Road, Rm L351
Evanston, IL 60208

All current course information is available at:

<http://www.mccormick.northwestern.edu/eecs/courses/index.html>

Graduate students should make it a habit of checking the above webpage when planning the courses to be taken in subsequent quarters and then proceed with a discussion with the respective academic advisors (and populating the data in the Graduate Students Tracking System (GSTS)).

Other useful information (e.g., forms, jobs-posting, announcements of visits by companies/recruiters, etc.) can be found at:

<http://www.mccormick.northwestern.edu/eecs/current-students/index.html>

Lastly: EECS organizes various social events throughout the Academic Year (bonfires, pizza-parties, GEECS coffee and bagels, etc.); these will be announced regularly by email.

1.2 General Admission Requirements

The primary objective of the admission process in the EECS Department is to determine an applicant's qualifications and judge the applicant's prospects for success in their desired program of study. To maintain a proper balance between department resources and the size of the graduate student population, we must limit offers of admission to the most qualified applicants. Thus, our admission process is highly selective and competitive in nature.

The deadline for **PhD** applications is **December 15** of the respective year for applicants who wish to be admitted to the program starting in the Fall Quarter of the subsequent academic year. The deadline for **MS** applications¹ is typically around the **end of April** of the year during which an applicant plans to start in the Fall Quarter.

Requests for admission and financial aid for doctoral students are reviewed during Winter Quarter. It is the policy of the department that students begin their programs in Fall Quarter. Under special circumstances, students are allowed to begin in the Winter or Spring Quarter. A typical applicant is expected to have a B.S. in electrical engineering, computer engineering, computer science, or a related discipline from a recognized institution. Highly qualified candidates with other academic backgrounds may also be considered. The specific undergraduate preparation required for graduate study depends on the program and the area of specialization. An applicant with insufficient undergraduate preparation in any particular area, but well qualified in every other respect, may be required to take certain undergraduate courses as soon as possible after enrolling at Northwestern. A student will be informed of such a requirement at the time of admission, along with grade expectations.

The Graduate School (TGS) website <http://www.tgs.northwestern.edu/admission/index.html> provides a means to navigate through the application process for graduate study at Northwestern University. Importantly, note that all applicants for graduate study in the EECS Department must submit verbal, quantitative, and analytical scores from the Graduate Record Examination (GRE). If an applicant has already obtained an MS degree from a U.S. institution, then GRE scores are not needed for PhD admission. However, GRE scores are required for all applicants who wish to be considered for a university fellowship.

1.3 Financial Aid

PhD Students

The policy of the McCormick School is to admit only those students for whom financial support can be provided in the form of Northwestern (e.g. Cabell and Murphy) Fellowships, research assistantships, and teaching assistantships. Students who have financial support from outside institutions or government grants will also be considered for admission. However, if such internal (McCormick, EECS Department) or external (company, institutional fellowship, government) financial support is not provided, then the EECS Department will not recommend admission of the student to The Graduate School.

MS-Only Students

The EECS Department encourages MS-only students, especially from industry, to apply. However, the Department does not provide financial support to MS-only students. Such students can be supported by a company, government, external fellowship, or be self-supported. **MS students are not eligible for teaching assistantships or research assistantships.**

¹ NOTE: MS applicants are *only* admitted for a Fall Quarter start date. This is to avoid any problems with the course sequence

1.4 Student Responsibilities and Academic Misconduct

It is the responsibility of each graduate student to ensure that all the requirements of The Graduate School (TGS) and the EECS Department are met, given the program they select; that necessary examinations are properly scheduled; and that deadlines dependent on current Northwestern University calendars are observed. The current procedures and degree requirements of the EECS Graduate Programs are detailed in this Manual.

Students should always consult with the EECS Department Student Affairs Office (Tech, L-351, eeesgrad@northwestern.edu) first to execute procedures, confirm requirements, and obtain paperwork for exams and various other procedures (e.g. visa related issues). In addition, students are strongly urged to consult regularly with their faculty advisors.

Official notices about degree program progress, financial aid and other important notices are sent to each student's official email and mail boxes.

Students are responsible for checking their official Northwestern <name>@u.northwestern.edu email accounts on a regular basis, no less than once a week.

Students are responsible for checking their official department mailbox on a regular basis, no less than once per month.

All students at Northwestern University are responsible for knowing the University's policies on academic integrity. The principles and possible consequences of academic misconduct are documented at:

<https://www.northwestern.edu/provost/policies/academic-integrity/principles.html>

Students found guilty of academic misconduct, such as cheating on coursework or plagiarizing research, by definition are failing to make satisfactory academic progress, and hence subject to be placed on academic probation.

<https://www.tgs.northwestern.edu/about/policies/satisfactory-academic-progress.html>

Students must be particularly vigilant in programming courses. Unless the instructor for the course has explicitly documented otherwise in the course syllabus:

- Code you submit must be your own.
- Copying and adapting someone else's code is not allowed.
- Studying someone else's solution for a specific assigned problem is not allowed.
- This includes code from a friend, an online article, or online coderepository.
- Letting another student study your solution is not allowed.

If an instructor concludes that cheating has occurred, they will submit the evidence to your Dean for adjudication. Penalties for cheating will depend on the specifics of the case. They can range from loss of points on the assignment in question, a reduction in letter grade for the course, or even failure in extreme circumstances.

1.5 Graduate Internships & Post-Graduation Employment

A grad student wishing to combine research work with industrial experience may, with the permission of their advisor, elect to participate in the Crown Family Graduate Internship Program. This experience permits the student to gain a broader understanding of some problems that could serve as the background for a thesis or project. For more on the program, see [Section 3.2.e](#) of this Manual.

International students who seek employment in the US upon graduating, are on an F-1 or J-1 visa, are in good academic standing, and have a valid I-20 should be aware that the visa status required for legal employment in the US after graduation is called OPT, and it **MUST BE APPLIED FOR 3-4 MONTHS BEFORE GRADUATION**. Without submitting this application in advance, you will not be able to transition smoothly from the F-1 or J-1 student status to the OPT visa status, and any such interruption may delay or prohibit your employment with a US employer. The International Office (IO) assists students with collection and submission of the required documents. In addition to consulting with your advisor, you should also schedule a meeting at least one month in advance of the OPT submission deadline to ensure you have enough time to collect the needed documentation.

2. MS Program

This section discusses the process of obtaining an MS degree with the EECS department. Unless otherwise specified, all the items pertain to all three divisions (EE, CE and CS).

2.1 MS Degree Options

Each student pursuing an MS degree in the EECS Department must declare their intention to follow one of the degree plans (A, B, or C) summarized below. The student's declaration is subject to approval by their advisor. We recommend that this declaration be made during the second (Winter) quarter, but we require that it be made no later than May 1st of the third (Spring) academic quarter.

Plan A (Thesis MS Degree): In this plan, a student declares their intent to earn the MS degree by completing a formal thesis that reports substantial original research results. Under this plan, a maximum of three units of EECS 590 research credit can be counted toward the 12-unit requirement for the MS degree. All requirements for the thesis MS, including coursework and approval of the thesis by the student's MS Examination Committee, must be successfully completed before the end of the seventh academic quarter (Spring quarter of the second year).

Thesis Requirements

A successful thesis has two components: a written document and an oral defense of the research. These are judged by a committee, headed by the thesis advisor, who is the committee head. One week prior to the oral defense, the student must provide a complete draft of the thesis to the committee. The defense should take between 30 minutes and 1 hour. Upon a successful defense, the committee will suggest edits to the document if any are required.

Once the advisor approves the final thesis, the student must submit the thesis as an EECS technical report. The thesis is not considered complete until this step has been taken. Instructions for submission are at the following link:

<http://www.mccormick.northwestern.edu/eecs/research/tech-reports/submit-technical-report.html>

The minimum MS thesis committee size is two people: the thesis advisor and one other faculty member. There must be at least 2 EECS faculty members on the thesis committee. They must both be on the graduate faculty. The thesis advisor must have a primary or secondary appointment in the student's program of study.

The MS thesis must conform to the formatting guidelines of a doctoral thesis, as specified by the graduate school at the following link:

<https://www.tgs.northwestern.edu/documents/policies/dissertation-format-guidelines.pdf>

There is no specific length for a thesis. Historically, they tend to be roughly 30 pages in the double-spaced graduate school thesis format. This is not a required length. The length must be negotiated with the thesis committee.

IMPORTANT: In Spring term, the Graduate School requires **all thesis defenses to be completed ONE MONTH before the end of the quarter**, if the student is to graduate in the Spring term. Deadlines in other quarters are not as early. Consult the Office of the Registrar's academic calendar for deadlines for each quarter.

Plan B (Project MS Degree): In this plan, a student declares their intent to earn the MS degree by

completing a project and writing a project report that contains results based on existing theory and techniques or experimental verifications. A maximum of two units of EECS 590 research credit can be counted toward the 12-unit requirement for the MS degree. All requirements for the project MS, including all coursework and approval of the project report by the student's MS Examination Committee, must be successfully completed before the end of the sixth academic quarter (Winter quarter of the second year).

Project Requirements

A project requires a written final document, approved by an examination committee.

The minimum committee size is 2: the advisor and one other faculty member. There must be at least 2 EECS faculty members on the thesis committee. They must both be on the graduate faculty. The project committee chair must have a primary or secondary appointment in the student's program of study.

Format of project document: It is recommended (but not required) that the project document conform to the formatting guidelines of a doctoral thesis, as specified by the graduate school at the following link:

<https://www.tgs.northwestern.edu/documents/policies/dissertation-format-guidelines.pdf>

Length of project document: There is no specific length for a project document. The length must be negotiated with the committee.

Once the advisor approves the final project document, submitting the project as an EECS technical report is not required.

Plan C (Course MS Degree): In this plan, the student must satisfactorily complete 12 courses approved by the student's advisor. The choice of courses must represent a coherent program of study that prepares the student for advanced work in a specific field. All requirements for the course MS degree must be satisfactorily completed before the end of the fifth academic quarter (Fall quarter of the second year).

Note that EECS 590 cannot be counted as a credit for a course-only based MS degree. The purpose of EECS 590 is to get students involved in research beyond the traditional course experiences. Hence, EECS 590 can only be applied towards the MS project option or the MS thesis option.

Time Limits: An MS student who does not meet the plan's completion deadline, and who does not successfully petition the EECS Department for an extension of that deadline, will be placed on academic probation for a maximum of two academic quarters. At that point, the Department retains the option to dismiss the student in question.

2.2 Advising and Course Requirements

Advising

Each MS student is assigned an academic advisor upon admission, based on the student's interests. However, the student's preferences and interests may change, especially if they elect to follow the project or thesis degree plan, which usually (but not always) entails the completion of one or more EECS 590 research units. This may require the student's transition to a new advisor. Such a transition involves the following steps: (1) The student notifies the current assigned advisor; (2) The EECS Department Student Affairs Office records the advisor change in the Graduate Student Tracking System (GSTS).

Each MS student must consult with their advisor before registering online for courses on CAESAR. Failure to do so could result in poor course selection that would delay completion of the student's MS degree, or even result in academic probation due to poor grades.

Course Requirements Common to CE, CS and EE

Typically, one unit of credit equals one course.

Twelve (12) units of graduate-level credits are required for any EECS MS degree.

All of the 12 units must be at the 300-level or above and must count for graduate coursework.

EECS 317 cannot be counted toward the MS degree for CE and CS students (EECS 339 should be taken instead). EE students can count EECS 317 towards this requirement.

EECS 301 and 302 do not count toward any EECS MS degree. They are intended for undergraduate students only.

Six (6) of the 12 units must be courses from within the degree program (CE, CS or EE).

See the program-specific requirements to learn which courses count within the degree program. EECS 499 (independent study) cannot count as a within-program course for any EECS MS degree. EECS 317 cannot count as a within-program course for any EECS MS degree.

Three (3) of the 12 units must be at the 400-level or above.

EECS 590 research units do not count towards 400-level course credits.

EECS 499 does count towards the 400-level course requirement.

Up to three (3) of the 12 units can be from graduate coursework outside EECS

This is subject to the approval of the student's advisor and the Co-Director of Graduate Studies of the degree program. These units can apply to either the requirement for 300-level or 400-level courses. It is important to consult with the academic advisor prior to enrolling in any course outside EECS.

Master's students engaged in research should enroll in either EECS 499 or EECS 590.

EECS 499 and EECS 590 courses are appropriate for MS students wishing to participate in research.

EECS 499 can be taken for credit regardless of the MS degree option (course-only, project, or thesis). EECS 499 is graded in the letter grade scale.

EECS 590 can be taken for credit only for project or thesis MS degrees. EECS 590 is graded in the P/N (pass / no-pass) scale.

The maximum allowable credits for EECS 499 and EECS 590 are:

- Course MS: up to three credits of EECS 499, and zero credits of EECS590.
- Project MS: up to three credits of EECS 499, and up to two credits of EECS590.
- Thesis MS: up to three credits of EECS 499, and up to three credits of EECS590.

Additional Course Notes

Courses that can be taken for a letter grade must be taken for a letter grade to be counted towards the degree.

All coursework for the MS degree must be taken within The Graduate School (TGS) of Northwestern University.

Coursework must be completed with a composite grade-point average of B (3.0) or higher.

MS students must consult with their academic advisor before enrolling in courses to avoid taking courses that do not count towards their degree.

Courses completed for undergraduate credit at Northwestern or elsewhere cannot be repeated for graduate credit.

EECS Course Credit Waivers

An MS student may petition to have at most three course credits waived, based on the student's graduate level courses taken previously at another program. Only coursework that has **not** been applied to a completed graduate degree will be considered for transfer credit for an MS degree. A petition for such a waiver must include complete documentation (e.g. syllabus, assignments, projects) of the content of the graduate level course the student wants to transfer. The student should identify which EECS course they petition for a waiver. The contents of these two courses should match substantially for a successful petition. The student must also provide an official transcript, sent directly to the department, which shows the grade received for each course used for transfer credit.

The coordinator of this EECS Department course will review the petition and make a recommendation. All such waivers are ultimately subject to the approval of the advisor, the Co-Director of Graduate Studies of the degree program (CE, CS, EE), and the EECS Director of Graduate Studies.

2.2.1 Electrical Engineering Specific Requirements

In addition to the requirements laid out in the rest of Section 2, students pursuing a MS in Electrical Engineering have the additional requirements described in this section.

Establishing Background: All MS Students in Electrical Engineering (including BS/MS students) must provide evidence of having sufficient background in the field as follows:

1. **Northwestern BS/MS students:** Must have completed the undergraduate EE core sequence (EECS 221, EECS 222, EECS 223, EECS 224, EECS 225) prior to or concurrent with beginning their Master's studies. This is the only option allowed for Northwestern BS/MS students.
2. **MS students new to Northwestern:** Must have completed a BS in EE degree at a previous university, the equivalent of the undergraduate EE core sequence (EECS 221, EECS 222, EECS 223, EECS 224, EECS 225) from another institution, or must take any courses missing from this EE core sequence prior to or concurrent with starting their Master's studies.

Coursework in Electrical Engineering: To ensure that students receive sufficient training in Electrical Engineering, 6 of the 12 required credits must be for courses taught by faculty whose primary appointment is in Electrical Engineering: EECS 303, 307, 308, 332, 333, 359, 360, 363, 374, 378, 379, 381, 382, 383, 384, 385, 388, 389, 390, 391, 398, 401, 402, 403, 404, 405, 406, 407, 410, 420, 421, 422, 425, 428, 431, 432, 433, 475, 478, or an EECS 395/495 course taught by a faculty with primary appointment in Electrical Engineering, as listed here:

https://www.mccormick.northwestern.edu/eecs/people/faculty/?academic_division=Electrical%20Engineering%20primary

A maximum of one credit of Design, Technology, and Research (EECS 315/497) may be applied to the EE MS degree.

2.2.2 Computer Engineering Specific Requirements

In addition to the requirements laid out in the rest of Section 2, students pursuing a MS in Computer Engineering have the additional requirements described in this section.

To ensure that students receive sufficient training in Computer Engineering, 6 of the 12 required credits must be from one of the courses listed below. Note that **EECS 499 Independent Study and EECS 590 Project/Thesis courses do not count towards the 6-core CE course requirement.**

A. Any course from the categories below:

I. Digital Design & VLSI

| | |
|--------------|--|
| EECS 303 | Advanced Digital Logic Design |
| EECS 355 | ASIC & FPGA Design |
| EECS 357 | Introduction to VLSI CAD |
| EECS 391 | VLSI Systems Design |
| EECS 392 | VLSI Systems Design Project |
| EECS 393/493 | Advanced Low Power Digital and Mixed-Signal Integrated Circuit Design EECS |
| EECS 459 | VLSI Algorithmics |
| EECS 326 | Electronic System Design I |
| EECS 327 | Electronic System Design II |

II. Embedded Systems

| | |
|------------|-----------------------------------|
| EECS 346 | Microprocessor System Design |
| EECS 347-1 | Microprocessor Systems Project I |
| EECS 347-2 | Microprocessor Systems Project II |
| EECS 390 | Introduction to Robotics |

III. Computer Architecture

| | |
|--------------|---|
| EECS 361 | Computer Architecture |
| EECS 362 | Computer Architecture Project |
| EECS 368/468 | Programming Massively Parallel Processors with CUDA |
| EECS 452 | Advanced Computer Architecture |
| EECS 453 | Parallel Architectures |
| EECS 456 | Modern Topics in Computer Architecture |

IV. Software Systems

| | |
|----------|---|
| EECS 351 | Introduction to Computer Graphics |
| EECS 321 | Programming Languages |
| EECS 322 | Compiler Construction |
| EECS 323 | Code Analysis and Transformation |
| EECS 339 | Introduction to Database Systems |
| EECS 343 | Operating Systems |
| EECS 455 | Distributed Computing Systems |
| EECS 446 | Kernel and Other Low Level Software Development |
| EECS 350 | Introduction to Computer Security |
| EECS 354 | Network Penetration and Security |

V. Parallel and Distributed Computing

| | |
|--------------|---|
| EECS 358 | Introduction to Parallel Computing |
| EECS 368/468 | Programming Massively Parallel Processors with CUDA |
| EECS 455 | Distributed Computing Systems |
| EECS 333 | Introduction to Communication Networks |
| EECS 340 | Introduction to Computer Networking |

EECS 467 Parallel and Distributed Database Systems
EECS 453 Parallel Architectures

VI. Algorithms

EECS 332 Introduction to Computer Vision
EECS 336 Design and Analysis of Algorithms
EECS 390 Introduction to Robotics
EECS 356 Introduction to Formal Verification
EECS 459 VLSI Algorithmics
EECS 375/475 Machine Learning: Foundations, Applications, and Algorithms

B. Any non-zero-credit 300-level or above taught by faculty with a primary appointment in CE:

Alok Choudhary
Jie Gu
Nikos Hardavellas
Larry Henschen
Josiah Hester
Russ Joseph
Gokhan Memik
Seda Ogrenci-Memik
Hai Zhou
Qi Zhu

C. The following courses with temporary catalog numbers:

EECS 395/495 Internet-of-Things Sensors, Systems, and Applications
EECS 395/495 Modeling and Synthesis of Cyber-Physical Systems EECS
EECS 395/495 Advanced Digital System Design with FPGAs
EECS 395/495 Blockchain and Cryptocurrency
EECS 395/495 Biometrics
EECS 495 Introduction to Database Systems
EECS 395/495 Technology Infrastructure: Concepts, Requirements, Design and Operation EECS
EECS 396/496 Systems Programming in Rust
EECS 396/496 Computational Geometry
EECS 396/496 Data Science Seminar
EECS 396/496 Special Topics in Swarms and Multi-robot Systems
EECS 396/496 Quadrotor Design and Control
EECS 396/496 Programming Languages Seminar EECS
EECS 397/497 Advanced Topics in Compilers EECS
EECS 397/497 Internet of Things Networks Seminar
EECS 397/497 Wireless and Mobile Health

2.2.3 Computer Science Specific Requirements

In addition to the requirements laid out in the rest of Section 2, students pursuing a MS in Computer Science have the additional requirements described in this section.

Establishing Background: All MS Students in Computer Science (including BS/MS students) must provide evidence of having sufficient background in the field in one of 3 ways:

- 1. Northwestern BS/MS students:** Must have completed the undergraduate CS core sequence (EECS 111, EECS 211, EECS 212, EECS 213, EECS 214) **prior to beginning** their Master's studies. Students who have not completed the core sequence will not be admitted to the BS/MS program in CS. No course taken at another university can substitute for a core class, unless it is accepted as transfer credit towards an undergraduate degree program at Northwestern University. **This is the only option allowed for Northwestern BS/MS students.**
- 2. Preliminary Examination:** Prior to their first quarter of study, MS students in Computer Science must take a preliminary exam covering topics in our undergraduate CS core sequence (EECS 111, EECS 211, EECS 212, EECS 213, EECS 214). The preliminary exam is offered only once per year in the week before fall term. It is the responsibility of the students to arrive on campus in time to take this exam. This option is not allowed for BS/MS students.
- 3. Intensive Program Design Course:** Those who do not pass the preliminary exam must enroll in "EECS 295 Intensive Program Design" during their first quarter of study at Northwestern University and receive a grade of B or higher. This is a 2-credit course that teaches remedial skills that CS students should have prior to beginning a MS program. It is offered only in the fall quarter of each year and does not count towards the 12 required credits for the MS degree. This option is not allowed for BS/MS students. This option is not allowed for transfers from another program.

Coursework in Computer Science: To ensure that students receive sufficient training in Computer Science, 6 of the 12 required credits must be for Computer Science courses:

The following courses all count as CS courses: EECS 303, EECS 313, EECS 314, EECS 315, EECS 321, EECS 322, EECS 325, EECS 330, EECS 331, EECS 332, EECS 335, EECS 336, EECS 337, EECS 338, EECS 339, EECS 340, EECS 343, EECS 344, EECS 345, EECS 346, EECS 348, EECS 349, EECS 350, EECS 351-1, EECS 351-2, EECS 352, EECS 354, EECS 361, EECS 368, EECS 369, EECS 370, EECS 371, EECS 372, EECS 394, EECS 415, EECS 440, EECS 441, EECS 444, EECS 450, EECS 469, EECS 473-1, EECS 473-2, EECS 474.

A maximum of one credit of Design, Technology, and Research (EECS 315/497) may be applied to the CS MS degree.

All courses taught under the 396, 397, 496, and 497 numbers also count as CS.

No 395/495 course counts as a CS course, although they do count towards the requirement that 9 of the 12 courses in the MS must be from within EECS.

Other courses, if taught by faculty with a primary appointment in CS may count as CS courses. Consult with your advisor to confirm such a course counts as a CS course prior to registration. Faculty whose primary appointment is computer science are listed here:

http://www.mccormick.northwestern.edu/eecs/people/faculty/?academic_division=Computer_Science_primary

2.3 Residency Requirements

According to TGS, the minimum residency requirement for the MS degree is the equivalent of three quarters of full-time registration in graduate courses. Full-time registration is defined as three or four course units per quarter. Refer to the TGS website for details about residency requirements:

<http://www.tgs.northwestern.edu/about/policies/masters-degree-requirements.html>

Note that the residency requirement also applies for CPT (Curriculum Practical Training), which enables MS students to take a summer internship during their studies.

2.4 Enrollment Options to Maintain Resident Student Status

There are a number of non-classroom courses that may, at times, be used to maintain residency and student status. Below is a brief guide to these courses. Before enrolling in any non-classroom course, especially a special registration course listed below, be sure to consult with your academic advisor and the EECS graduate student services staff.

Special Registration Courses: These courses are used to maintain student status in cases where registering for research or classroom courses is not appropriate.

- TGS 512: This course does not apply to the 12 units that must be completed for any EECS MS degree. It may, however, be a way to save money if a student has already completed the required 12 units and needs to maintain student status while completing a project or thesis. Tuition for TGS 512 is \$100 and students do not need to pay the activity fee. Students may enroll in TGS 512 only if they have completed 12 units. When enrolled in TGS 512, the student cannot enroll in additional classes.
- TGS 500: This course is for advanced doctoral research and may not be applied to the 12 units needed to complete any EECS MS degree. Do not enroll in this course as a MS student.
- TGS 588: TGS 588 is available to international students pursuing an MS degree that have completed 10 or 11 units and are completing their thesis or project. TGS 588 allows additional concurrent enrollments. Students will need permission from the EECS department office to enroll in this course. This course is typically used for international students to help them maintain full-time status. TGS 588 cannot be counted towards the 12 units required for the MS degree. This course is not graded. Enrolling in TGS 588 can be repeated for multiple quarters. Each enrollment requires permission from The Graduate School. This option may save money for some graduate students who need to maintain full-time status for visa purposes, but who would have reached the needed 12 credits without being full time in a quarter. As a point of comparison, in the 2018-19 academic year, tuition for EECS 590 is \$6418, while tuition for TGS 588 is \$6014.

2.5 Degree Completion

To complete the MS degree, students must complete the following steps:

- Complete the Application for Degree (AFD) in CAESAR. This form can be found by navigating to For Students > TGS Forms > Application for Degree (AFD).
- Complete the Master's Degree Completion (MDC) form in CAESAR. This form can be found by navigating to For Students > TGS Forms > TGS Master's Completion. Note: students will see other TGS forms related to Prospectus and Final Exam. These forms are only for PhD students; for Master's students, these may be disregarded.

- **For Coursework students:** in the section for Committee Members, students should enter the name of their EECS academic advisor (and/or division DGS if necessary) as the Chair. In either the Co-Chair or Member box, students should enter either Prof. Stephen Tarzia (for EE or CE) or Prof. Christopher Riesbeck (for CS)
- **For Project and Thesis students:** students should enter the names of their committee members, and then enter either Prof. Stephen Tarzia (for EE or CE) or Prof. Christopher Riesbeck (for CS).
 - One week prior to defending their project or thesis, students should complete the EECS Examination Request Form, which can be found online at:
<http://eecs.northwestern.edu/popular-forms>.
 - The student's file will be checked for any missing documents, grades, etc. The file and the EECS Examination Request Form will be given to the committee chair prior to the defense. After the defense, the form must be signed by all committee members, and the committee chair should return the completed paperwork and file to the EECS Department Graduate Office.
 - Once the advisor approves the final thesis, the student must submit the thesis as an EECS technical report. The thesis is not considered complete until this step has been taken. Instructions for submission are at the following link:
<http://www.mccormick.northwestern.edu/eecs/research/tech-reports/submit-technical-report.html>
 - Project students are not required to submit their project document as a technical report.
- **For ALL students:** students should send an email to eecsgrad@northwestern.edu with a list of the 12 courses they intend to use toward their MS degree. For BS/MS students, please note that these 12 courses must NOT be counted toward the undergraduate degree.

2.6 Transfer to a different MS program

Whether it is Computer Engineering, Computer Science, or Electrical Engineering, students admitted to an MS program in EECS are expected to complete the program of study to which they applied and were admitted. During the application process, our admissions committee carefully reviews all the materials submitted, and students are admitted with a belief that they will succeed in the program to which they were admitted. Only in very rare cases are MS students allowed to transfer to a different program within EECS.

Our MS programs have limited capacity and we only accept a small percentage of applicants. We cannot accept all those who wish to transfer to them from other programs at Northwestern. Only in very rare cases are transfers from an MS in another Northwestern department allowed.

All requests to transfer to one of our EECS MS programs must be approved by both the Co-Director of Graduate Studies for the student's current degree program (in the case of a transfer within EECS) or current Director of Graduate Studies (if the student is in a program outside EECS) and the Co-Director of Graduate Studies for the desired EECS program. The current advisor will also be consulted during the evaluation of the request. **Transfer is not guaranteed.** If approved, **transfers may require one or more additional quarters of study**, since curriculum progress towards the original program is one of the prerequisites of a transfer request.

Transfers to Computer Science can be particularly difficult, due to the program requirement for establishing appropriate background described in [Section 2.2.3](#) of this Manual. This background requirement applies to all transfer students.

Transfer requests are accepted for review after the student has demonstrated success as evidenced by **at least one quarter of graded work** in the current degree program and, at the earliest, transfer requests may be placed in the 2nd (typically Winter) quarter - to be effective starting in the 3rd (typically Spring) quarter of their first year.

A student should request a program transfer no later than the date by which the students declare their degree plan: May 1 of the academic year of their admission, at the latest. In exceptional cases, requests for transfers will be considered after this date, however, they will be subject to extra review by the student's advisor, the Graduate Committee, and the Director of Graduate Studies.

Students who do not take any courses in the program to which they were admitted will not be considered for transfer until after they complete at least one quarter of graded work in the original program.

As a prerequisite, **a faculty member with primary affiliation in the desired program must express written consent to advise the student.** For Master's students who have selected the Thesis or Project option, this letter must explicitly state the advisor's willingness to advise the student on a multi-quarter research project. Furthermore, students must provide a valid justification for wanting to transfer their program of study that must also be validated by the new advisor.

Requests for program transfer should be signed by the students' academic advisor and submitted to the EECS Graduate Student Affairs Office and will be forwarded to the appropriate Graduate Chair(s) for evaluation. They will evaluate the transfer request by taking various factors into account. These factors include, but are not limited to:

- Success in the original program of study to which the student was admitted.
- The expected ability of the student to successfully complete graduate work in the desired program of study. Relevant evidence includes transcripts and work experience.
- The justification provided by the student for requesting a transfer. This justification must be based on something more substantial than a simple desire to change the title of the degree.
- The strength of the support expressed by a faculty member who has agreed to advise the student in the desired program.

2.7 Part-time Graduate Program

Graduate students may pursue their MS studies in the EECS Department on a part-time basis. Only USA citizens and permanent residents may be enrolled part time. This is because the United States government does not give student visas to those enrolled part time.

Please discuss the details with the academic advisors and email the EECS Department Student Affairs Office eecsgrad@northwestern.edu for further information.

2.8 Pursuing a PhD After Being Admitted to the MS Program

There is no guarantee for admission into the PhD program for students who are currently in the MS-only program. However, successful students may be considered for a transfer. MS students are required to complete at least 2 quarters of residency in the MS-only program before they can be considered for a transfer to the PhD program. If a student is planning to apply to continue with the PhD program he/she should first contact the EECS Department Student Affairs Office (eecsgrad@northwestern.edu). The proper process for application for a transfer will be advised. Each student's case will be evaluated subject to the same procedures that apply to external PhD applicants.

2.9 Probation, Exclusion, and Appeal Processes

Failure to meet academic integrity standards (e.g. cheating on coursework), failure to meet the requirements for academic progress (e.g. maintaining a minimum of 3.0 GPA), and failure to meet milestones related to project or thesis work may result in The Graduate School placing a student on probation. In cases of milestones, students may petition to The Graduate School for an extension of the milestone's deadline if a convincing reason and evidence is provided. Failure to remedy the missing requirements by the given due date may ultimately result in exclusion from The Graduate School and the respective program.

Once an MS student is placed on probation, the EECS department reserves the right to review the student's case and subject the student to additional penalties during probation as relates to their standing in the EECS degree program including, but not limited to, loss of funding and/or exclusion from the EECS graduate program. For more information on probation and appeal processes for probation, please refer to **The Graduate School's guidelines**:

<http://www.tgs.northwestern.edu/about/policies/satisfactory-academic-progress.html>

3. PhD Program

This section covers the official **Milestones (3.1)** in a PhD student career and the **Registration (3.2)** requirements mandated by Northwestern University and the EECS Department for each year. In addition to the requirements outlined below, each Research Interest Group specifies its own Program of Study (PS) with its own additional requirements. [See Section 4](#) (Programs of Study) of this manual for details.

3.1 Milestones

This section outlines the set of milestones that must be passed in an EECS doctoral program. Any student not meeting the milestones will be considered not in good standing and therefore will be ineligible for fellowships, traineeships, teaching or research assistantships, and scholarships. Students who do not meet published requirements of satisfactory academic progress may be excluded from The Graduate School (TGS). Students who have taken time off for family or other approved leave will have appropriate accommodations made to adjust their milestones.

Student may view these milestones and the deadlines for completion in the Graduate Student Tracking System (GSTS). After logging into the GSTS Dashboard, the list of milestones can be viewed under “Show Profile > Milestones.”

For additional information, see TGS PhD Degree Requirements webpage and TGS Satisfactory Academic Progress webpage:

<http://www.tgs.northwestern.edu/about/policies/phd-degree-requirements.html>

<http://www.tgs.northwestern.edu/about/policies/satisfactory-academic-progress.html>

3.1.a Selection of an Advisor for the PhD Dissertation

PhD students are required to have a permanent advisor by the end of their third quarter (typically spring quarter). To continue as a student in the EECS doctoral program beyond the third quarter of study, every PhD student must have an academic advisor that is willing to serve as their advisor and who has an approved plan for funding. **The advisor must have an academic appointment in EECS.** This includes faculty with a courtesy appointment in EECS.

For PhD students, an initial faculty advocate is assigned to each student at the time of admission to assist with planning the first academic quarter of study. This advocate is most likely a faculty member with research interests closest to those stated in the student’s application, and therefore a strong candidate for serving as the student’s eventual faculty advisor. The student is not required to select the faculty advocate as their advisor.

The student’s advisor will serve as the primary contact with the EECS Department, and should be chosen to match the student’s academic program of study and research interests (see [Section 4](#)).

If a PhD student decides to change advisors at any point in time during their studies, their previous advisor and the Director of Graduate Studies (DGS) must be consulted and provide formal approval in writing.

In each quarter, the study plan should be approved by the student's advisor prior to registration. Graduate courses in electrical engineering, computer engineering, computer science, and related fields are described in this manual and the TGS bulletin.

The normal full-time program of graduate study is three units per academic quarter. The maximum permitted is four units. All students receiving financial aid in the form of fellowships, research assistantships, or teaching assistantships must register as full-time students.

3.1.b Admission to Candidacy

As stated in the TGS PhD Degree Requirements webpage noted above, a PhD student must be admitted to candidacy by the end of the third year of study, which falls on the last date of the 12th academic quarter.

A student failing to meet this milestone will be considered not in good academic standing, and therefore will be placed on academic probation, as per the TGS Satisfactory Academic Progress webpage noted above.

Admission to candidacy requires meeting the academic requirements of the Program of Study of one of the six EECS Department Research Interest Groups and passing the Qualifying Exam of that Research Interest Group as described in [Section 4](#) of this manual.

3.1.c Qualifying Examination

When you are ready to take a Research Interest Group's Qualifying Exam, fill in the **EECS Examination Request Form** available online at <http://eecs.northwestern.edu/popular-forms>. Instructions for scheduling an exam time and reserving a room are on this form. Note that the content of qualifying exams will vary across different Programs of Study within the department. [Section 4](#) specifies the requirements for each program of study.

Verify the availability of your proposed faculty committee on the date chosen for your exam, and obtain all required signatures. Your advisor must return the completed form to the EECS Student Affairs Office (Tech L351). The Student Affairs Office staff will submit the necessary information to TGS.

3.1.d Prospectus (Dissertation Proposal)

Students must have a prospectus (dissertation proposal) approved by a faculty committee no later than the end of the fourth year of study, which falls on the last date of the 16th academic quarter. A student failing to meet this milestone will be considered not in good academic standing and therefore will be placed on academic probation, as per TGS Satisfactory Academic Progress Guidelines (see link in [Section 3.1](#)). A minimum of three individuals must serve on this committee. At least two members of this committee, including the committee chair, must be members of the Northwestern University Graduate Faculty, as explained here: <http://www.tgs.northwestern.edu/resources-for/faculty>).

At least two members, including the committee chair, must be faculty in the EECS Department. See [Section 4](#) of this Manual for any additional Research Interest Group requirements for the committee. Upon formation of the prospectus committee, the student should submit the PhD prospectus form through TGS Forms in the CAESAR website:

<http://www.northwestern.edu/caesar/>

3.1.e Dissertation and Defense

Every PhD candidate is required to prepare a dissertation indicating evidence of original and significant research. Read “Dissertation Formatting Guidelines” that can be downloaded from TGS at this link:

<http://www.tgs.northwestern.edu/documents/policies/dissertation-format-guidelines.pdf>

For the Final Exam, a student follows the same procedure as for the PhD Qualifier Exam (above in [Section 3.1.b](#)), although now the student clicks the PhD Final Exam tab in CAESAR.

Four weeks prior to the PhD Final Exam date, the student submits the EECS Examination Request form (available at <http://eecs.northwestern.edu/popular-forms>) **signed by all members of the committee.** The student must make sure that they have met all the degree requirements of the EECS Department as detailed in this manual and all requirements of Northwestern’s Graduate School, as specified on their website (see link in [Section 3.1](#)).

An announcement of the student’s Final Exam is then posted in the EECS Department. The student’s file is checked for any missing documents, grades, etc., that need to be completed for the Final Exam and awarding of the PhD degree. This file and the *Report of the Committee on Examination of Candidate form* is given to the student’s advisor prior to the Final Exam and must be in the examination room for reference. Upon conclusion of the Final Exam, this *Report* must be signed by all of the committee members. Then, the advisor immediately returns the completed and signed paperwork to the EECS Student Affairs Office.

Once the PhD dissertation has been approved by the committee, and all subsequent edits and revisions are completed by the student, the student must submit the dissertation online via the ProQuest website: <http://www.etdadmin.com/cgi-bin/home>. At this point, a TGS Student Services representative reviews the formatting and confirms via email that the dissertation is acceptable or notifies the student if changes need to be made.

3.1.f Teaching Requirement

In February 2014, the McCormick School of Engineering approved the following PhD teaching requirement effective with the PhD class matriculating in Fall 2014:

- (1) All students earning a PhD degree from a McCormick program must meet one of the following requirements:
 - (a) Serve as an instructor of an undergraduate course, or
 - (b) Serve as a full-time teaching assistant (20 hours a week) in an undergraduate course for at least one quarter, or
 - (c) Serve as a part-time teaching assistant (6-8 hours a week) in an undergraduate course for at least three quarters, or
 - (d) Meet a Departmental teaching requirement that has been approved by The Graduate School.
- (2) Teaching assistant positions must involve some face-to-face contact with students (office hours, lab or problem session, lecturing) in addition to grading.

In addition to options (1a), (1b), and (1c) listed above, PhD students in the EECS Department can choose to satisfy the teaching requirement by registering for two quarters of *Teacher Trainee* (TT) duties. Each TT quarter’s work assignment involves a half-time teaching assistantship with some additional class involvement beyond grading homework or staffing a help desk. Typically, during the academic quarter, the TT prepares and presents one class lecture or designs one new homework assignment.

First-time TT students should register for GEN_ENG 545 (Teaching Experience) to receive credit for their effort. Second-time TT students should register for GEN_ENG 546, which is zero credit but does place on their transcript

recognition of their contribution.

Note that a PhD student cannot be both a teaching assistant and a TT in the same academic quarter. Also, registrations in GEN_ENG 545 and GEN_ENG 546 are only for TT students.

Also note that a student **will not be able to graduate until one of the teaching requirements listed above is fulfilled**. When a student files their thesis proposal, the student must also file a form listing what part of the teaching requirement has been fulfilled at that point and what, if any, teaching requirement has yet to be fulfilled.

3.2 Registration and Course Requirements

3.2.a The Graduate School Requirements

Full-time registration is three units (courses) per quarter. Typically, students take three courses per academic quarter and may not take more than four courses per quarter.

TGS requires PhD students to complete eight academic quarters of full-time registration, consecutively over two years, including summers. This is the residency requirement.

TGS requires a minimum of 9 graded graduate level courses (**note: EECS requires a minimum of 15 graded graduate level courses**). The cumulative grade point average over these graded courses must be a B average (3.0 GPA) or higher.

Prior to meeting the residency requirement, students that are not enrolled full-time in graded coursework, should register for *EECS 590 Research* to maintain full-time study. Refer to the TGS General Registration Policies webpage for all detail:

<http://www.tgs.northwestern.edu/about/policies/general-registration-policies.html>

After residency requirements are met (eight full time quarters), a student who is receiving funding should begin registering for TGS 500 and not EECS 590. TGS 500 carries a lower tuition rate.

Doctoral who have met the residency requirement but are not receiving funding during a quarter may register for TGS 512. This is a low-cost course designed to maintain student status.

Any alterations in the residency timeline can be managed through Leave of Absence requests. Per TGS Continuous Registration Policy (see TGS General Registration Policies webpage link in the preceding two paragraphs), all PhD students must be registered at Northwestern University in each of the Fall, Winter and Spring terms until all degree requirements have been completed, including dissertation submission to The Graduate School.

Students receiving financial support (assistantships or fellowships) must be registered as full-time students, including summer quarters. Such students must also maintain satisfactory academic progress, as per TGS Satisfactory Academic Progress Guidelines (see link in [Section 3.1](#)).

3.2.b Common EECS Course Requirements

The EECS Department requires 15 graded units of graduate coursework for the PhD. Coursework includes EECS 499, but not EECS 590 (Research). At least 6 units should be at the 400 or 500 levels, not counting EECS 545 and EECS 546 (the two credits PhD students can earn for teaching).

The Graduate School requires 8 quarters of full-time residency. This translates to 24 credits of coursework, including the 15 credits of graded coursework. EECS 590 research units make up the remainder of the units required to achieve residency.

A PhD student's advisor or EECS Research Interest Group may require more than the minimum number of courses. In such cases, the number of EECS 590 research units will be reduced correspondingly.

EECS 499 is reserved for projects that are not directly related to the research required for the PhD thesis or for readings in specific subjects for which the EECS Department has no regular courses. EECS 499 is not intended to replace or augment the required units of EECS 590 research for either the MS or PhD degrees. Computer engineering and electrical engineering students are limited to two units of EECS 499.

GEN_ENG 519: The National Science Foundation (NSF) requires everyone being paid on NSF grant money to complete Responsible Conduct of Research (RCR) training. For doctoral students, this requirement is satisfied by enrolling in GEN_ENG 519. All PhD students are required to complete this training in their first year.

3.2.c Programs of Study within the chosen Research Interest Area

Each doctoral student must complete all requirements imposed by their chosen Program of Study ([Section 4](#)) within their Research Interest Area, in addition to all requirements of the EECS doctoral program itself ([Section 3](#)).

3.2.d Petitioning for Course Credit or Substitution

A PhD student may petition to have at most six (6) EECS Department course credits waived, based on graduate level courses taken previously elsewhere. This petition must include complete documentation (e.g. syllabus, assignments/projects) of the content of the course from the student's previous institution that most closely matches the EECS Department course credit to be waived. The student must provide an official transcript, sent directly to the department, which shows the grade received for each course used for waiver credit.

Note, that for every course waived, the student must enroll in one credit of EECS 590 Research in its place. This is because waiving the course does not lessen the residency requirement imposed by The Graduate School.

The coordinator of this EECS Department course will review the petition and make a recommendation. All such waivers are ultimately subject to the approval of the advisor and the EECS Director of Graduate Studies.

3.2.e Internships during Graduate Study: The Crown Family Graduate Internship

Students who wish to take advantage of an internship opportunity are encouraged to sign up for The Graduate School General Curriculum *CRDV_510 Crown Family Graduate Internship* course for 0 units. A prerequisite for this course is a written approval of the PhD advisor. Students may register for this course for no more than three academic quarters and no more than two consecutive academic quarters.

Enrolling in CRDV_510 when doing an internship maintains the student in full-time status at the University and **carries no tuition cost**. Full-time status is usually required to maintain US visa status for international students, and registration for CRDV_510 helps Northwestern administration, including TGS, record graduate student progress and track our external research collaboration efforts.

For more details about the Crown Family Graduate Internship Program, contact the McCormick School's Associate Dean for Graduate Studies and Research or visit the following URL:

<http://www.mccormick.northwestern.edu/students/graduate/fellowships-internships/crown-family.html>

International students who chose to do an internship must also apply for Curricular Practical Training (CPT) authorization for any off-campus internships. "Off-campus" is defined as any internship that takes place outside of Northwestern University. For more information on applying for CPT, please visit the International Office's website:

<http://www.northwestern.edu/international/living-working/student-employment/curricular-practical-training.html>

3.3 Probation, Exclusion, and Appeal Processes

Each quarter, students are expected to make satisfactory academic progress. Satisfactory academic progress is defined, in part, as meeting the requirements set by The Graduate School:

<http://www.tgs.northwestern.edu/about/policies/satisfactory-academic-progress.html>

Students are also expected to meet additional EECS requirements for satisfactory progress, as follows:

- Students found to be guilty of academic misconduct (e.g. cheating on coursework or plagiarism of research) are defined as failing to make satisfactory academic progress.
- PhD students are required to have a permanent advisor by the end of their third quarter (typically spring quarter). To continue as a student in the EECS doctoral program beyond the third quarter of study, every PhD student must have an academic advisor with an appointment in EECS and an approved plan for funding.
 - If a doctoral student has no advisor by the last day of a given quarter, or if the current advisor has notified the student and the Director of Graduate Studies of unsatisfactory research progress during a given quarter, this will constitute failure to make satisfactory academic progress as defined by the program.
- Students are required to make satisfactory progress towards their thesis as evaluated by their thesis advisors.

Failure to meet requirements for satisfactory progress may result in The Graduate School placing a student on probation.

Students may petition to The Graduate School for an extension of a milestone's deadline if a convincing reason and evidence is provided. Failure to remedy the missing requirements by the given due date may ultimately result in exclusion from The Graduate School and the respective program.

For more information on probation and appeal processes for probation, please refer to The Graduate School's guidelines.

Once a PhD student is placed on probation, the EECS department reserves the right to review the student's case and subject the student to additional penalties during probation as relates to their standing in the EECS degree program including, but not limited to, loss of research assistantship (RA) funding, loss of departmentally funded support such as teaching assistantships (TA), loss of and/or exclusion from the EECS graduate program.

Students who fail to make satisfactory academic progress according to the EECS Program requirements in a given quarter will be put on probation for the following quarter. The student must use the probationary quarter to seek an alternate advisor or improve progress to receive a report of satisfactory progress with their current advisor. At the end of the probationary quarter, if the student has secured an advisor who can report satisfactory progress, the student will be removed from probationary status. Otherwise the department may make a recommendation of exclusion (dismissal) to The Graduate School. No further funding from the department or advisor will be provided to the student after the end of the probationary quarter.

4. Doctoral Programs of Study (PS)

General PhD requirements for Northwestern University (e.g. residency requirements, grade requirements, deadlines to reach milestones) are discussed in Section 3 of this manual. This includes information on common course requirements across all EECS doctoral Programs of Study.

In addition to the common requirements, every EECS doctoral student must select a degree area in which they complete a Program of Study (PS) under a faculty member that specializes in that area. Each program has specific requirements for the coursework, qualification exam, and dissertation prospectus. The EECS Department offers the following Programs of Study:

| | |
|-------------------------------|---|
| PhD in Electrical Engineering | 4.1 Solid State & Photonics |
| | 4.2 Signals & Systems |
| PhD in Computer Engineering | 4.3 Computer Engineering |
| PhD in Computer Science | 4.4 Computer Systems |
| | 4.5 Computing, Algorithms, and Applications |
| | 4.6 Cognitive Systems |
| | 4.7 Graphics & Interactive Media |

Each subsection that follows describes one program of study.

4.1 Solid-State and Photonics (Electrical Engineering)

Research Area Description:

Solid-state engineering focuses primarily on the science and technology of semiconductors for quantum structures and devices operating from the ultraviolet up to far infrared. Quantum devices are fabricated using the most advanced semiconductor synthesis technologies (MOCVD, MBE, gas source MBE, *etc.*), as well as microfabrication techniques (high-precision photolithography, e-beam evaporation, RTA, reactive-ion etching, *etc.*). The quantum devices are fully tested at each step in the fabrication process using advanced characterization techniques (diffraction, SEM, TEM, photoluminescence, Hall, *etc.*) Most of the research is performed within the Center for Quantum Devices (CQD), in a clean-room environment similar to what is found in industry. These quantum devices are in high demand by today's applications. Ultraviolet lasers and photodetectors are needed for astronomy, space communications and the monitoring of engines and heat sources. Red, green and blue (RGB) solid-state lasers are needed for high-brightness full-color displays and optical data storage (CD, DVD). High-power 0.808 μm , 0.98 μm , 1.3 μm , and 1.5 μm lasers and VCSELs are needed for medical applications and fiber optical communications. Infrared lasers (*e.g.* quantum cascade lasers), photodetectors (*e.g.* QWIPs), and focal plane arrays (FPAs) are needed for chemical analysis and night vision.

Optical systems and technology focuses on microcavity lasers, nanostructures, quantum and nonlinear optics, integrated optics, fiber optics and infrared waveguide devices, fiber-optic communications, and imaging through turbulence. Special emphases include: applications of novel quantum amplifiers in optical communications, imaging, and cryptography; devices for terabit per second WDM and TDM optical networks; and applications of computational techniques in integrated and nonlinear optics.

Faculty: Aydin, Grayson, Gu, Ho, Khalili, Kumar, Mohseni, Razeghi, Shahriar, and Yuen

The courses in this area are divided into Core Courses and Area-Specific Courses as follows:

PhD Coursework

Core Courses (Group A)

Each student is required to take **five** of the following courses:

| | |
|----------|------------------------------------|
| EECS 382 | Photonic Information Processing |
| EECS 383 | Fiber-Optic Communication |
| EECS 388 | Microelectronic Technology |
| EECS 401 | Fundamentals of Electronic Devices |
| EECS 402 | Advanced Electronic Devices EECS |
| EECS 403 | Quantum Semiconductors |
| EECS 404 | Quantum Electronics |
| EECS 405 | Advanced Photonics |

| | |
|------------|---------------------------|
| EECS 406 | Nonlinear Optics |
| EECS 408-1 | Classical Electrodynamics |

Area-Specific Courses (Group B)

Elective courses in Solid-State and Photonics include:

| | |
|------------|---|
| EECS 333 | Introduction to Communication Networks |
| EECS 381 | Electronic Properties of Materials |
| EECS 384 | Solid-state Electronic Devices |
| EECS 385 | Optoelectronics |
| EECS 386 | Computational Electromagnetics and Photonics |
| EECS 389 | Superconductivity and its Applications |
| EECS 407 | Quantum Optics |
| EECS 408-2 | Computational Electrodynamics |
| EECS 409 | Semiconductor Lasers |
| EECS 422 | Random Processes in Communications and Control I EECS |
| EECS 423 | Random Processes in Communications and Control II EECS |
| EECS 424 | Noise and Fluctuation in Physical/ Engineering Systems |
| EECS 425 | Quantum Electronics II–Noise, Modulation, and Quantum Properties of Laser Emissions |
| EECS 427 | Optical Communications |
| EECS 428 | Information Theory |
| EECS 429 | Selected Topics in Quantum Information Science and Technology |
| EECS 454 | Advanced Communications Networks |
| ESAM 411 | Differential Equations of Mathematical Physics |

With approval of their advisors, students can also take advanced courses (400-level) in Applied Mathematics, Physics and Astronomy, and Materials Science and Engineering, to fulfill the requirements of the Area-Specific Courses.

PhD Qualifying Examination

Photonics Option: For PhD students in the Photonics subgroup Program of Study (PS), the PS evaluation will be made by the Solid-State and Photonics PS Committee, appointed by the group director, on the basis of the following criteria:

- (1) the student's performance in coursework;
- (2) the student's performance in research, and
- (3) an oral exam.

The oral examination requirement can be bypassed if so deemed by the student's advisor.

The oral examination is conducted by a team selected by the PS committee and consists of at least three faculty members with expertise in the examination area. Some of the committee members can be faculty members from outside the EECS Department. The exam is offered once each year, and students must sign up for the exam with the director of the PS committee. A student is given two attempts to pass the PS evaluation. However, each student must get the PS evaluation done by the end of the student's second year in order to continue in the PhD program. Extension of this deadline for up to one year may be granted by the EE Co-Director of Graduate Studies if requested by the student's advisor.

SSE Option: For PhD students in the Solid-State Engineering (SSE) subgroup, the PS evaluation, the student's advisor approves the exam and selects the qualifying exam committee members from experts in the field. At least three committee members must be from the EECS Department. The committee evaluation is based on the student's performance in coursework, an oral presentation, and a written proposal detailing the student's future research plans. The qualifying exam must be approved no later than just before the beginning of the fourth year of study (or end of third year).

PhD Prospectus

In addition to the PS evaluation, a student must get a thesis prospectus approved by the end of the fourth year. The procedure for this approval is as follows. The student selects three faculty members, one of which must be their advisor, for the thesis committee. The student produces a written proposal and makes a presentation to this committee. Following an evaluation of the written proposal and the performance of the student during the presentation, the committee decides on approving the prospectus. A student is given two attempts to receive this approval.

PhD Dissertation

Dissertations must be formatted according to the [Dissertation Formatting Guidelines document](#). Dissertations not conforming to these instructions will not be accepted: <http://www.tgs.northwestern.edu/about/policies/phd-degree-requirements.html#dissertation>

4.2 Signals & Systems (Electrical Engineering)

Research Area Description:

Communications, Networks, and Control focuses on communications, telecommunications and communication networks, and control theory. Specific areas of study include: mobile wireless multi- user communication, estimation and detection, wireless networks, resource allocation in communication networks, data network protocol design, network performance modeling and analysis, nonlinear and robust control, and stochastic hybrid systems.

Signal Processing focuses on the digital representation and algorithmic manipulation of speech, audio, image and video signals. Specific topics within this general area include: image and video processing; recovery and compression; multimedia signal processing; filter design and rank-order operators; image and video transmission; medical and biomedical signal processing; medical imaging; and, algorithms for medical instrumentation.

Faculty: Argall, Berry, Butz, Freeman, Guo, Honig, Katsaggelos, Lee, Pappas, Sahakian, Tumblin, Wei, C.-H. Wu, Y. Wu, and Yuen

Core Courses

All students must take the following four core courses:

| | |
|----------|---|
| EECS 307 | Communications Systems |
| EECS 359 | Digital Signal Processing |
| EECS 410 | System Theory |
| EECS 422 | Random Processes in Communication and Control I |

Elective Courses

Each student must select three from the following list of seven courses:

| | |
|----------|--|
| EECS 332 | Digital Image Analysis |
| EECS 333 | Introduction to Communication Networks |
| EECS 360 | Introduction to Feedback Systems |
| EECS 378 | Digital Communications |
| EECS 420 | Digital Image Processing |
| BME 383 | Cardiovascular Instrumentation |
| BME 402 | Advanced Systems Physiology |

Area-Specific Courses

In addition, each student must complete a sequence of courses in an area of specialization according to the recommendation of the advisor. These courses may be in Signals & Systems and other areas. Elective courses in Signals & Systems may include:

| | |
|----------|---|
| EECS 363 | Digital Filtering |
| EECS 374 | Introduction to Digital Control |
| EECS 380 | Wireless Communication |
| EECS 418 | Advanced Digital Signal Processing |
| EECS 420 | Digital Image Processing |
| EECS 421 | Multimedia Signal Processing |
| EECS 423 | Random Processes in Communications and Control II |
| EECS 426 | Signal Detection and Estimation |
| EECS 427 | Optical Communications |
| EECS 428 | Information Theory |
| EECS 432 | Advanced Computer Vision |
| EECS 454 | Advanced Communication Networks |
| EECS 478 | Advanced Digital Communications |
| EECS 485 | Local Area Networks |
| BME 384 | Biomedical Computing |
| BME 402 | Systems Physiology |

PhD Program of Study Evaluation

The Signals & Systems Program of Study (PS) evaluation will be done by the Signals & Systems PS Committee on the basis of a student's performance in coursework, research, and the Signals & Systems PS written exam. The PS exam consists of two parts. The first part of the exam covers communication systems (EECS 222 and EECS 307), signal processing (EECS 359), linear systems (EECS 410), and probability and random processes (Math 310 and EECS 422). All students are responsible for all materials in the first part of the exam (the core exam). The second part of the exam (elective) covers digital image analysis (EECS 332), communication networks (EECS 333), control (EECS 360), digital communications (EECS 378), image processing (EECS 420), and cardiovascular instrumentation (BME 383; also offered as EECS 395/495). Each student is responsible for three of the six areas in the second part of the exam.

The PS Exam and corresponding evaluation are offered twice per year at the end of the Fall and Spring Quarters, generally on the Monday (core) and Tuesday (elective) of the week immediately following final exam week. Students must sign up for the PS Exam with the EECS Graduate Office. Students can choose between the Fall and Spring exams, and they will be given two attempts to pass the evaluation. However, each full-time student must pass the evaluation by the end of the student's second year to continue in the PhD program. Part-time students must pass the exam by the end of their third year.

PhD Prospectus

In the Signals & Systems Group, the prospectus is the student's proposal defense. The proposal is a written document describing the student's PhD research topic, with background and prior work and proposed work. The proposal defense is an event during which the student presents the proposal to their PhD committee who then decide whether or not to pass the student either conditionally or unconditionally. Upon passing the prospectus the student then completes the research and writes and eventually defends the PhD thesis.

PhD Dissertation

Dissertations must be formatted according to the [Dissertation Formatting Guidelines document](#). Dissertations not conforming to these instructions will not be accepted: <http://www.tgs.northwestern.edu/about/policies/phd-degree-requirements.html#dissertation>

4.3 Computer Engineering

Research Area Description

Research in Computer Engineering includes (but is not limited to) the analysis and design of integrated circuits, computer architecture, computer systems, high-performance and parallel computing, distributed computing, embedded systems, real-time systems, software systems, and mobile and wearable computing.

Faculty

Primary Affiliation: A. Choudhary, J. Gu, N. Hardavellas, L. Henschen, J. Hester, R. Joseph, G. Memik, S. Ogrenci-Memik, H. Zhou, Q. Zhu

Secondary Affiliation: N. Alshurafa, Y. Chen, P. Dinda, I. Mikhelson, A. V. Sahakian, P. Scheuermann

Required Coursework

Areas of study in the Computer Engineering fall into six tracks: digital design and VLSI, embedded systems, computer architecture, software systems, parallel and distributed computing, and algorithms. The tracks are shown below.

All CE PhD students must take **EECS 361: Computer Architecture**

In addition, a student must complete at least 6 courses from the list provided below. These courses must fulfill at least three of the six tracks. A track is fulfilled when the student completes at least two of the track's courses. A course that is listed in two different tracks can fulfill both track requirements (but can be counted only once towards the 6 credits). Additional 300-level classes and a 400-level and above courses from the EECS department can fulfill track requirements with the consent of the advisor.

A. Digital Design & VLSI

| | |
|--------------|---|
| EECS 303 | Advanced Digital Logic Design |
| EECS 355 | ASIC & FPGA Design |
| EECS 357 | Introduction to VLSI CAD |
| EECS 391 | VLSI Systems Design |
| EECS 459 | VLSI Algorithmics |
| EECS 393/493 | Advanced Low Power Digital and Mixed-Signal IC Design |

B. Embedded Systems

| | |
|----------|------------------------------|
| EECS 346 | Microprocessor System Design |
| EECS 390 | Introduction to Robotics |

C. Computer Architecture

| | |
|--------------|---|
| EECS 361 | Computer Architecture |
| EECS 368/468 | Programming Massively Parallel Processors with CUDA |
| EECS 452 | Advanced Computer Architecture |
| EECS 453 | Parallel Architectures |

D. Software Systems

| | |
|----------|-----------------------------------|
| EECS 351 | Introduction to Computer Graphics |
| EECS 321 | Programming Languages |

| | |
|----------|----------------------------------|
| EECS 322 | Compiler Construction |
| EECS 339 | Introduction to Database Systems |
| EECS 343 | Operating Systems |
| EECS 455 | Distributed Computing Systems |

E. Parallel and Distributed Computing

| | |
|--------------|---|
| EECS 358 | Introduction to Parallel Computing |
| EECS 368/468 | Programming Massively Parallel Processors with CUDA |
| EECS 455 | Distributed Computing Systems |
| EECS 333 | Introduction to Communication Networks |
| EECS 467 | Parallel and Distributed Database Systems |
| EECS 453 | Parallel Architectures |

F. Algorithms

| | |
|------------|-------------------------------------|
| EECS 332 | Digital Image Analysis |
| EECS 336 | Design and Analysis of Algorithms |
| EECS 390 | Introduction to Robotics |
| EECS 356 | Introduction to Formal Verification |
| EECS 459 | VLSI Algorithmics |
| EECS 510 | Social Media Mining |
| IEMS 450-1 | Mathematical Optimization I |
| IEMS 450-2 | Mathematical Optimization II |
| IEMS 457 | Integer Programming |

Admission to PhD Candidacy

To be admitted to PhD candidacy, a student must maintain good academic standing in the CE PhD program. A student maintains good academic standing in the CE PhD program if the faculty with primary appointments in Computer Engineering determine that the student's progress in research and academics is satisfactory. The student's progress is assessed formally through periodic meetings of the faculty with primary appointments in Computer Engineering.

A PhD student in good standing is automatically admitted to PhD candidacy after completing 9 courses and obtaining a GPA of 3.5 or higher. If previous graduate-level coursework completed at another institution was transferred, up to 3 of these courses can be used to contribute to the GPA calculation subject to the approval of the advisor and CE co-DGS.

If a student fails to meet any of the above criteria, a committee of three faculty with Primary Affiliations in Computer Engineering proctors an oral exam of the student in the immediately following academic quarter to determine whether the student can be admitted to the candidacy. This committee is formed by the advisor of the student. A student failing this exam will be excluded from the program.

PhD Prospectus

In addition to the Program of Study evaluation, a student must get a thesis prospectus approved by the end of the fourth year. The procedure for this approval is as follows. The student selects three faculty members, one of which must be his/her adviser, for the thesis committee. The student produces a written proposal and makes a presentation to this committee. Following an evaluation of the written proposal and the performance of the student during the presentation, the committee decides on approving the prospectus.

The prospectus committee is formed according to the following rules:

1. There are at least three members who currently have full-time faculty appointments at Northwestern University. At least two of these must be faculty members of the EECS Department. At least two (including the chair) must be members of the Graduate Faculty of Northwestern.
2. With the approval of the Department Chair, there may be one additional voting member of the committee from outside Northwestern. This person should be an expert in the area of the student's research. The Department Chair may request a resume from this outside member before the appointment.
3. Others may be invited to attend the examinations as nonvoting members of the committee.

If a PhD candidate changes their adviser and/or research topic after taking the PhD Oral Qualifying Examination, the student may be required to take another oral examination on the new research topic.

PhD Dissertation

Dissertations must be formatted according to the [Dissertation Formatting Guidelines document](#). Dissertations not conforming to these instructions will not be accepted. The requirements are listed at: <http://www.tgs.northwestern.edu/about/policies/phd-degree-requirements.html#dissertation>

4.4 Computer Systems (Computer Science)

This section outlines the specific procedures and requirements for a Computer Science (CS) PhD in this Program of Study. For requirements that apply to all doctoral students in EECS (e.g. number of course credits and teaching requirements) [see Section 3](#) of this Manual. For general requirements that apply to all Northwestern doctoral students (e.g. deadlines for achieving milestones, such as the qualifying exam and the prospectus), see the links to The Graduate School's website in [Section 3.1](#) of this Manual.

Research Area Description

Research in Systems includes a broad range of topics, including (but not limited to) data mining, database systems, network security, programming languages, program development environments, network analysis; network protocols, peer-to-peer networks, resource virtualization and ubiquitous computing.

Affiliated Faculty

Fabian Bustamante, Yan Chen, Christos Dimoulas, Peter Dinda, Jennie Duggan, Robby Findler, Aleksandar Kuzmanovic

Course Requirements

Breadth in Computer Science beyond Systems: Before taking qualifiers, each should have taken at least one course in each of the following areas: Theory, Artificial Intelligence, and Interfaces. Courses that satisfy those requirements are listed below.

- Theory: EECS 328, 335, 336, 356, 357, 457, 459. We strongly recommend that students become familiar with algorithms at least to the level of EECS336.
- Artificial Intelligence (AI): EECS 325, 337, 344, 348, 349. We strongly recommend that students become familiar with core AI and machine-learning topics as described in EECS 348 and 349.
- Interfaces: EECS 330, 332, 351, 352, 370

Breadth in Computer Systems: The expectation for students is that they have deep knowledge of systems, in general. To that end, we expect that you will take at least **six courses in the following areas. Of these six courses, you must take at least one course in each of Operating Systems, Networking, and Compilers**, unless, for some reason, appropriate courses are not offered. Courses that satisfy the breadth requirement are listed below.

- Architecture: EECS 361, 452, 453
- **Compilers: EECS 322 (required)**
- Databases: EECS 339
- Distributed Systems: EECS 345, 455

- Languages: EECS 321
- **Networking: EECS 340, 440 (1required)**
- **Operating Systems: EECS 343, 441, 443, 446 (1required)**
- Parallel Systems: EECS 358, 368, 468
- Performance Analysis: EECS 410, 442, 486
- Security: EECS 350, 354, 450
- Sensor Networks: EECS 369

You need not have taken these specific courses, but you should be familiar with their concepts and content. There are often additional EECS courses that may be appropriate for systems. Please consult online syllabi for these courses. With advisor approval, alternate graduate courses may be used to satisfy this requirement. Additionally, EECS 499 courses may be used with advisor approval.

Breadth Course Substitution: A student may already have satisfactory background in some area of general computer science or in computer systems, either through general knowledge or similar courses at another university. With advisor consent, one may substitute other courses. If the student feels they have satisfied any of these areas, they are encouraged to approach the relevant course coordinator for an assessment, or their advisor if the coordinator is unable to provide an assessment.

Depth in Systems: How to acquire depth in your area will be determined by your advisor. Generally, it takes the form of taking additional graduate-level courses and doing guided research and reading.

Qualifying Exam

The purpose of the Systems Qualifying Exam is to determine whether you have the essential prerequisites of being a doctoral-level researcher, namely:

Have you acquired a breadth of knowledge in computer science and computer systems? Do you have a depth of knowledge in your research area?

Can you do research?

Can you present your research well, both in written form and orally? Can you defend your research?

Can you think and discuss research extemporaneously? In other words, can you think on your feet?

If you do not meet these prerequisites, you will not pass the exam. In some cases, such as if you fail due to insufficient breadth or depth, you may be able to retake the exam. The exam can be retaken only once.

You should ask your advisor if you are prepared to take the systems Qualifying Exam. If he or she agrees, you should form a committee consisting of your advisor and at least two other Systems faculty members. Non-Systems faculty are also appropriate in some situations: you should ask your advisor. It is your responsibility to schedule the exam and reserve a conference room for it. Exams have no set length, but past exams have taken from 2 to 6 hours. Exams are private: only your committee and you are in the room.

The Qualifying Exam begins with your presentation of a significant piece of research that you have done. One week before the exam, you must supply the committee with a paper about the work. A conference or workshop talk/paper is ideal. The committee will ask you tough questions about the content of the presentation and the work. The purpose of this part of the exam is to determine whether you are capable of doing research, presenting it, and defending it well.

In the next stage of the Qualifying Exam, each of your committee members will have the opportunity to ask you questions. Any technical question related to computer science is fair; however, the focus will be on systems. Many faculty members prefer to start with a question designed to test your breadth or depth of knowledge in computer science. The committee may follow up on such questions, probing to find out what you know and what you don't know. The committee is particularly interested in how you respond to questions in areas you don't know or that you don't know the answer to. This is a common situation in doing research and the committee wants to know how you respond to it. It is appropriate and encouraged to ask questions of the committee. The committee also wants to see how you respond in an intellectual dialog.

After the exam, the committee will deliberate. Four outcomes are possible:

- **Pass.** The student successfully completed of the qualifying exam.
- **Conditional Pass.** While the student did well on the majority of the exam, the faculty have identified an area of weakness that must be addressed before a "pass" is reported. A letter will outline what actions must be taken to address the weakness.
- **Fail with Possibility of Retake.** The student failed the qualifying exam, but there is evidence that the student could pass, given a specific course of action. A letter will outline what needs to be done before the student may retake the exam.
- **Fail without Possibility of Retake.** The student did not pass the exam and either (1) this is their second and final attempt or (2) the committee determines there is no course of action likely to result in passing the qualifying exam prior to The Graduate School's deadline.

The Qualifying Exam can be retaken only once. A student cannot be admitted to candidacy without passing this exam.

Thesis Committee

The thesis is judged by a committee that is chosen by the student in consultation with the student's advisor. The committee commits to reading and commenting on the thesis proposal, attending the thesis proposal defense, providing guidance and advice as the thesis work progresses, reading and commenting on the dissertation, and attending the thesis defense.

The committee must consist of at least three faculty members in the EECS Department that are also faculty in The Graduate School and at least one external committee member. This requirement is specific to Systems in Computer Science and supersedes the minimum committee required by The Graduate School.

The committee must include the student's advisor, who is generally the chair of the committee. In most cases, the faculty member should be drawn from the Systems Group, although exceptions can be made. **The external committee member should be from outside Northwestern and should hold a PhD.** Exceptions can be made in consultation with the student's advisor, but a member external to the EECS Department is required.

It is the responsibility of the student to form the committee and to schedule it for the proposal and dissertation defenses.

Thesis Prospectus

The thesis prospectus is a document written by the student that describes the proposed thesis. The proposal is generally 10-15 pages long and prepared in consultation with the advisor. It must contain:

- Thesis statement. What is the specific research problem being addressed and what is the proposed solution?
- Related work. What have other people done in this area and why is the proposed solution new?
- Prior work. What work has the student done already that suggests that he is capable of addressing the problem?
- Work plan. What the student proposes to do. Of course, research often takes one in unplanned directions.

The point of the work plan (and schedule) is to describe what path is currently expected.

- Expected contributions. What artifacts and results are expected?
- Schedule. When will the major elements of the work plan be completed? Notice that writing the dissertation is an important task.

The document must be given to the members of the committee **at least one week** before the proposal defense. It is not necessary to make the proposal available online.

The proposal defense is an open, advertised, public talk, given in front of the committee and any members of the EECS Department who care to attend. The open segment of the proposal defense is followed by a closed segment with only the committee and the student.

The student must schedule the defense, making sure all his/her committee members are there physically or via phone conference. The student must assure that the proposal defense is advertised to the EECS Department at least one week before it occurs. It will specifically be posted as a thesis proposal talk.

The talk is a summary of the thesis proposal and a defense of its ideas. It's the final sanity check before the thesis work begins and is very important.

Generally, a proposal talk lasts about 50 minutes, although there is no set time. Only clarification questions are permitted during the talk. After the talk, each member of the committee, in an order determined by the chair, will ask in-depth questions. Once the committee is finished, further questions will be solicited from the audience.

After public questions have been exhausted, the audience will leave and the committee may ask further private questions or raise other private concerns.

The student will then leave the room, and the committee will determine whether the student has passed or failed the proposal defense. The student will be informed whether they passed or failed on the day of the proposal defense. If the student passes the thesis proposal defense, we will immediately inform The Graduate School that the student's "thesis prospectus has been approved."

Thesis and Defense

The dissertation document must be complete, in draft form, before the dissertation defense can take place. It must be provided to the members of the committee at least one week before the defense is to take place. Generally, the student will have his advisor read and comment on the draft well before then.

The procedures for the dissertation defense are similar to those of the proposal defense. The defense is an open, advertised, public talk, given in front of the committee and any members of the EECS Department who care to attend. The open segment of the defense is followed by a closed segment with only the committee and the student.

The student must schedule the defense, making sure all the committee members are there physically or via phone/video. The student must assure that the defense is advertised to the EECS Department at least one week before it occurs. It will specifically be posted as a thesis defense talk.

The defense talk is a summary of the thesis work and a defense of its ideas and results. Generally, a defense talk lasts about 50 minutes, although there is no set time. Only clarification questions are permitted during the talk. After the talk, each member of the committee, in an order determined by the chair, will ask in-depth questions. Once the committee is finished, further questions will be solicited from the audience. After public questions have been exhausted, the audience will leave and the committee may ask further private questions or raise other private concerns.

The student will then leave the room, and the committee will determine whether the student has passed or failed the dissertation defense. In either case, the chair of the committee will inform the student describing the results of the committee's deliberation and what additional work, if any, is to be done.

If the student passes the thesis defense, we will report this to The Graduate School. At this point, the student needs only to deliver the final version of his/her dissertation in order to graduate.

Publishing a Technical Report of the Thesis

After a successful defense, the committee will, within 2 weeks, send comments on the dissertation draft to the student. The student will then complete any additional work and make the necessary changes to the dissertation. The student must deliver the final dissertation in two ways. First, he/she must turn it in to the library. Second, **the student is expected to publish the thesis as an EECS Department technical report.** The purpose of publishing the dissertation as a technical report is to make the thesis widely available to the public.

Additional Expectations and Requirements

Systems research necessarily involves computers and networks, often many of them. This research infrastructure does not manage or configure itself, nor does the systems support group support all aspects of research computing. Systems students are expected to help in configuring, updating, and maintaining the infrastructure for the Systems Group's overall benefit.

Good systems researchers build systems; they don't just talk about or simulate them. You must know at least one low-level systems programming language such as C or C++. You must know at least one high-level application programming language such as Java, Perl, Python, Scheme, Lisp, ML, or Matlab. If you haven't written a 1000+ line program in the language, you don't know it. If you haven't programmed on a multi-person project, you haven't programmed. You should look at the websites of the various labs that comprise the Systems Group to get a sense of the level of programming you should be able to implement.

By the end of your second year, we expect that you will have made significant research contributions that will also serve as a guide for the remainder of your time in the program.

4.5 Computing, Algorithms & Applications (Computer Science)

This section outlines the specific procedures and requirements for a Computer Science (CS) PhD in this Program of Study. For requirements that apply to all doctoral students in EECS (e.g. number of course credits and teaching requirements) see [Section 3](#) of this Manual. For general requirements that apply to all Northwestern doctoral students (e.g. deadlines for achieving milestones, such as the qualifying exam and the prospectus), see the links to The Graduate School's website in [Section 3.1](#) of this Manual.

Research Area Description

The research of the Computing, Algorithms & Applications (CAA) Group focuses on theory, discrete and continuous algorithms, and software implementations and applications. Current areas of application include bioinformatics, economic models, machine learning, auctions, social networks, energy, formal methods, networking, security, self-assembly, and VLSI CAD.

Affiliated Faculty

Anindya De, Jason Hartline, Ming-Yang Kao, Konstantin Makarychev, Aravindan Vijayaraghavan

Course Requirements

Each student in the CAA Group must earn at least a B+ in 3 courses from the following list:

- 496 - Graduate Algorithms
- 496 - Computational Complexity
- 496 - Mechanism Design
- 496 - Approximation Algorithms
- 496 - Theoretical Machine Learning

The student can substitute one of these courses with a different graduate-level theory course with the permission of the committee.

Qualifying Exam

The purpose of the CAA Group Qualifying Exam is to determine whether you have the essential prerequisites for being a doctoral-level researcher, namely:

- Have you acquired sufficient breadth of knowledge in computing and algorithms?
- Do you have a depth of knowledge in your research area?
- Can you present your research (or survey a research topic) well, both in written and oral form?

The Qualifying Exam Committee consists of your advisor and at least two other EECS Department faculty (who can be substituted by faculty from other departments at Northwestern with the consent of your advisor). The Qualifying Exam will typically take two hours in total.

You have two options for the Qualifying Exam: (a) you can present the results of research you have done (a conference or journal paper is ideal); or (b) you can present an in-depth survey of a research topic assigned to you by your advisor.

The topic of the presentation should be discussed with your advisor. Fourteen days before the exam, you must supply the committee with a document about the work you will present. In case you are presenting the results of your research, (option (a)) a full draft of the paper will suffice. The exam will begin with your presentation. This portion of your exam is open to the rest of the department. The committee will ask you questions about the

content of the presentation and the work.

The next stage of the exam is closed, with only you and your committee members in the room. Each of your committee members will have the opportunity to ask you technical questions related to your research area or the core courses you have taken. After the exam, the committee will deliberate. Four outcomes are possible:

- **Pass.** The student successfully completed of the qualifying exam.
- **Conditional Pass.** While the student did well on the majority of the exam, the faculty have identified an area of weakness that must be addressed before a “pass” is reported. A letter will outline what actions must be taken to address the weakness.
- **Fail with Possibility of Retake.** The student failed the qualifying exam, but there is evidence that the student could pass, given a specific course of action. A letter will outline what needs to be done before the student may retake the exam.
- **Fail without Possibility of Retake.** The student did not pass the exam and either (1) this is their second and final attempt or (2) the committee determines there is no course of action likely to result in passing the qualifying exam prior to The Graduate School’s deadline.

The Qualifying Exam can be retaken only once. A student cannot be admitted to candidacy without passing this exam.

Thesis Committee

There are no requirements beyond those specified by the EECS department and The Graduate School.

Thesis Prospectus

The prospectus must be approved by a faculty committee. A minimum of three individuals must serve on the prospectus committee. Upon formation of the prospectus committee, the student should submit the PhD Prospectus form through The Graduate School forms.

The prospectus document should be submitted to the committee at least **one week before the presentation** to allow time to read and critique it.

The prospectus defense is an open public talk, given in front of the PhD thesis committee and any members of the Northwestern community who care to attend. The talk should last approximately 50 minutes. The student will be informed whether they have passed or failed on the day of the proposal defense. In either case, the chair of the committee will write a formal letter to the student describing the results and what additional work, if any, is to be done.

Thesis and Defense

The thesis document should be submitted to the committee at least **two weeks before the presentation** to allow time to read and critique it.

The procedures for the PhD thesis defense are similar to those of the proposal defense. The defense is an open public talk, given in front of the committee and any members of the EECS Department who care to attend. The talk is a summary of the PhD thesis work and a defense of its ideas and results.

After a successful thesis defense, your committee will, within 7 days, send comments on the thesis draft to you. You will then complete any additional work and make the necessary changes to the thesis. You must deliver the finalized thesis to The Graduate School.

Additional Expectations and Requirements

You are expected to finish your PhD study in 4 - 5 years. Generally, you should make every effort to follow the following schedule:

1. Find a faculty member to be your PhD advisor no later than Spring Quarter of the first year;

2. Take the Qualifying Exam by Spring Quarter of the second year, and no later than the end of your third year;
3. Take the PhD thesis proposal defense by Spring Quarter of the third year.

In choosing an advisor, you should take the initiative to discuss with any faculty member who interests you upon your joining Northwestern University or even before then. You should engage in research as soon as possible, but the timing will depend on your academic background and should be decided in consultation with your advisor. In your first year or two, you will also be taking classes, but doing research will determine your success as a graduate student.

By the end of your 2nd year, you will take the CAA Group qualifying exam, which is described in detail below. The next step after the qualifying exam is to find a PhD thesis topic. A thesis proposal is presented after you have done substantial work, and the potential research contributions can be envisioned and defended. The final step is to write and defend a PhD thesis.

Students are encouraged to seek out summer funding of their own in the form of internships at quality research laboratories, if this is deemed to enrich their learning experience.

4.6 Cognitive Systems (Computer Science)

This section outlines the specific procedures and requirements for a Computer Science (CS) PhD in this Program of Study. For requirements that apply to all doctoral students in EECS (e.g. number of course credits and teaching requirements) see [Section 3](#) of this Manual. For general requirements that apply to all Northwestern doctoral students (e.g. deadlines for achieving milestones, such as the qualifying exam and the prospectus), see the links to The Graduate School's website in [Section 3.1](#) of this Manual.

Research Area Description

Work in this area focuses on: Understanding how minds work, from a computational perspective; Creating systems for helping people learn better and perform better, using principles of Cognitive Science; Using Artificial Intelligence (AI) techniques to create new forms of interactive entertainment.

Affiliated Faculty

Brenna Argall, Larry Birnbaum, Douglas Downey, Ken Forbus, Darren Gergle, Kristian Hammond, Larry Henschen, Michael Horn, Ian Horswill, Bryan Pardo, Christopher Riesbeck, Uri Wilensky; and Haoqi Zhang

Course Requirements

There are no specific coursework requirements beyond those specified by the EECS department and The Graduate School.

Coursework will vary depending on exact interests and background of each student. Someone deeply interested in cognitive science might take a number of courses in psychology. Someone interested in creating new kinds of educational software might take some of their courses in the School of Education and Social Policy. Someone interested in more applied AI might take some of their courses in human- computer interaction and interface design.

While the following courses are not required, each student should be conversant with the material in these courses, as their content is assumed knowledge in the Cognitive Systems Qualifying exam.

- EECS 325 Artificial Intelligence Programming
- EECS 337 Introduction to Semantic Information Processing
- EECS 338 Practicum in Intelligent Information Systems
- EECS 344 Design of Computer Problem Solvers
- EECS 348 Introduction to Artificial Intelligence
- EECS 349 Machine Learning
- EECS 371 Knowledge Representation

Qualifying Exam

The Cognitive Systems Qualifying Exam is a one-day written exam, traditionally the Monday or Tuesday after Finals week of Spring Quarter. The exam is open-book, open-notes, and graded anonymously. Graduate students must take the exam at the end of their second year.

After the exam, the committee will deliberate. Four outcomes are possible:

- **Pass.** The student successfully completed of the qualifying exam.
- **Conditional Pass.** While the student did well on the majority of the exam, the faculty have identified an area of weakness that must be addressed before a “pass” is reported. A letter will outline what actions must be taken to address the weakness.
- **Fail with Possibility of Retake.** The student failed the qualifying exam, but there is evidence that the student could pass, given a specific course of action. A letter will outline what needs to be done before the student may retake the exam.
- **Fail without Possibility of Retake.** The student did not pass the exam and either (1) this is their second and final attempt or (2) the committee determines there is no course of action likely to result in passing the qualifying exam prior to The Graduate School’s deadline.

The Qualifying Exam can be retaken only once. A student cannot be admitted to candidacy without passing this exam.

Thesis Committee

There are no requirements beyond those specified by the EECS department and The Graduate School.

Thesis Prospectus

All graduate students will write a thesis proposal before undertaking serious work on their PhD research. The written proposal must be approved by a CogSys Group-approved thesis committee. After approval, the student must give a public presentation of the thesis proposal.

The prospectus document should be submitted to the committee at least **one week before the presentation** to allow time to read and critique it. The oral component consists of a formal presentation of the proposed research to the thesis committee, as one might give at a departmental colloquium. You should plan the presentation for 45 minutes, with another 15 - 45 minutes for questions.

Thesis and Defense

The required format of the final thesis is governed by The Graduate School. Please consult their website for details.

The thesis document should be submitted to the committee at least **two weeks before the thesis defense** to allow time to read and critique it.

Two presentations are required. The actual defense of the thesis is an oral presentation, open only to faculty and other members of the University with PhD degrees. A public presentation of the thesis is required after the defense is passed.

Additional Expectations and Requirements

It is crucial to realize that, unlike undergraduate study, graduate school is primarily about research, not courses. We expect you to do well in your courses, naturally. However, we expect you to become involved in research starting in your first year. Independent-study projects are a good way to explore what kind of work you want to become involved in or just to wrap your head around something different if you are already involved in a project. Instead of a master's thesis, we encourage students to publish research in conferences and journals, starting early in the graduate career.

4.7 Graphics & Interactive Media (Computer Science)

This section outlines the specific procedures and requirements for a Computer Science (CS) PhD in this Program of Study. For requirements that apply to all doctoral students in EECS (e.g. number of course credits and teaching requirements) see [Section 3](#) of this Manual. For general requirements that apply to all Northwestern doctoral students (e.g. deadlines for achieving milestones, such as the qualifying exam and the prospectus), see the links to The Graduate School's website in [Section 3.1](#) of this Manual.

Research Area Description

Graphics & Interactive Media (GIM) is a Program of Study for students interested in human-computer-interaction, multimedia, graphics, audio processing, human computation and social computing.

Affiliated Faculty

Larry Birnbaum, Oliver Cossairt, Darren Gergle, Kristian Hammond, Michael Horn, Ian Horswill, Bryan Pardo, Jack Tumblin, Uri Wilensky, and Haoqi Zhang

Course Requirements

There are no specific required courses for GIM students. However, all GIM students are required to demonstrate proficiency in the subfields listed below.

- Fundamentals of Programming: EECS 111+ EECS 211+ EECS214
- Theoretical Computer Science (1 course): EECS 335, EECS336
- Systems (2 courses drawn from any of the following categories)
 - Computer architecture: EECS 361
 - Databases: EECS 339
 - Networking: EECS 340
 - Operating systems: EECS 343
 - Programming languages: EECS 321, EECS 322
- Graphics or media (1 course from any of the following categories)
 - Audio, visual or multimedia processing: EECS 351-1, EECS 351-2, EECS352
 - Computer games: EECS 370, EECS 396
- Cognitive and social systems (1 course from any of the following categories)
 - Artificial Intelligence: EECS 348, EECS 349, EECS 371, EECS474
 - Cognitive science: An advisor-approved cognitive science course
 - Social science: An advisor-approved social sciencecourse
 - Learning sciences: EECS 313

Proficiency means showing knowledge comparable to getting an A in an undergraduate course on the topic at a peer institution. For programming knowledge, proficiency may, at the discretion of the advisor and Co-Director of Graduate Studies for Computer Science, be demonstrated through significant work experience in the software industry. Students entering the doctoral program with an undergraduate degree in computer science will likely satisfy most or all of the requirements through coursework on their undergraduate transcript.

Any requirements not satisfied through prior coursework should be resolved by taking the appropriate course at Northwestern University. Students should discuss with their advisors to identify appropriate courses to take. Course numbers shown are courses offered at Northwestern University that would satisfy the requirement, but other courses may also apply.

It is the responsibility of the student to make a case for how each course taken at a prior institution satisfies a requirement. This may include providing their transcript, the syllabus of each class in question. This case should be made to the student's academic advisor. If there is any question about the applicability of a course after discussion with the advisor, the case should be brought to the Co-Director of Graduate Studies for Computer Science.

Students entering with an undergraduate degree in computer science should complete this work in their first year, those with undergraduate degrees in other areas should complete this within two years.

Qualifying Exam

The qualifying exam consists of presenting the results of a small-to-medium-sized completed research project to an examination committee of three members of the graduate faculty, at least two of which should have a primary, secondary or courtesy appointment in Computer Science. Although the project may be a component of a larger group project, the work reported on should be solely by the student, not joint work with other students.

What the exam consists of:

The exam has two parts: the written component and the oral component.

The written component consists of a mock (or real) conference paper on the project. Although the project need not be published work, the student should identify a conference in which the project could plausibly be published and write the paper to be consistent with the submission requirements (length, etc.) for that conference. The paper submitted to the committee should be a final version, approved by the student's advisor. In certain cases, a committee may agree to accept a dissertation proposal in lieu of a completed project paper. The paper should be submitted to the committee at least **two weeks before the presentation** to allow time to read and critique it.

The oral component consists of a formal presentation of the project, as one might give at a departmental colloquium. It should be roughly 45 minutes in length, with another 15 - 45 minutes for questions. The purpose of the oral exam is to probe the student's analytical and research skills, although the committee may ask whatever questions it feels are appropriate.

When to take the exam: The expectation is that the qualifying exam will be completed prior to the start of the student's third year in the program. In exceptional cases, this may happen later, subject to the deadlines specified by Northwestern's Graduate School on how late in the degree the exam may be taken without being placed on academic probation or being excluded from the graduate program.

Outcomes:

After the exam, the committee will deliberate. Four outcomes are possible:

- **Pass.** The student successfully completed of the qualifying exam.
- **Conditional Pass.** While the student did well on the majority of the exam, the faculty have identified an area of weakness that must be addressed before a "pass" is reported. A letter will outline what actions must be taken to address the weakness.
- **Fail with Possibility of Retake.** The student failed the qualifying exam, but there is evidence that the student could pass, given a specific course of action. A letter will outline what needs to be done before the student may retake the exam.
- **Fail without Possibility of Retake.** The student did not pass the exam and either (1) this is their second and final attempt or (2) the committee determines there is no course of action likely to result in passing the qualifying exam prior to The Graduate School's deadline.

The Qualifying Exam can be retaken only once. A student cannot be admitted to candidacy without passing this exam.

Thesis Committee

There are no requirements beyond those specified by the EECS department and The Graduate School.

Thesis Prospectus

The written component of the thesis prospectus specifies:

- The topic to address
- Why it's important
- The relevant work that has been done before on the topic
- How the student expects to improve upon existing relevant work
- A schedule for the work to be done. This is intended as a planning tool for you to help ensure plans are practical.

A typical prospectus length in GIM is roughly 15 to 20 pages.

The prospectus document should be submitted to the committee at least **one week before the presentation** to allow time to read and critique it. The oral component consists of a formal presentation of the proposed research to the thesis committee, as one might give at a departmental colloquium. You should plan the presentation for 45 minutes, with another 15 - 45 minutes for questions.

Thesis and Defense

The thesis document should be submitted to the committee at least **two weeks before the presentation** to allow time to read and critique it.

The procedures for the PhD thesis defense presentation are similar to those of the proposal defense. The defense is an open public talk, given in front of the committee and any members of the EECS Department who choose to attend. The talk is a summary of the PhD thesis work and a defense of its ideas and results.

After a successful thesis defense, your committee will send comments on the thesis draft to you. You will then complete any additional work and make the necessary changes to the thesis. You must deliver the finalized thesis to The Graduate School.

Additional Expectations and Requirements

None.