

# GUIDE FOR ARCHITECTURAL ENGINEERING GRADUATE STUDENTS

## Academic Year 2021-2022

Welcome to the Architectural Engineering Graduate Program! This document contains an outline of things you need to know about the program. It is by no means exhaustive, but it should help you get started. You are also suggested to refer to the following recourses:

- Graduate School Rules: <https://www.colorado.edu/graduateschool/policies>.
- All procedures, deadlines, and requirements by Graduate Schools: <https://www.colorado.edu/graduateschool/academic-resources/graduation-requirements>
- Pertinent forms for CEAE graduate students: <https://www.colorado.edu/ceae/current-students/graduate-studies/forms-graduate-students>

## 1. ARRIVING

### 1.1 Meet the Faculty

The first thing that you need to do upon arriving at the University is to meet (1) the CEAE Graduate Program Advisors and (2) the faculty member you will be working with (or the temporary advisor on your admission letter). Drop by their offices (or call/email to make an appointment) and get acquainted. If you have not formalized your research topics/ideas, you may want to talk with all faculty members to find out about the courses they teach, their research interests, and their roles in the program; at the same time, this allows them a chance to find out about your background and your interests. Specific backgrounds and areas of expertise for each faculty member can also be found at: <http://www.colorado.edu/ceae/faculty-staff/faculty>

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You are **required** to meet with your advisor (or your temporary academic advisor) to work out a course plan of study, which is an outline of all the courses that you plan to take for your degree. Options are discussed in the next section. You will need to obtain an official course plan sheet from the Graduate Program Advisor and fill out the contents, and get a signature from your advisor before the Graduate Program Advisor can lift the flag for course registration. Your course of study can be revised; you should meet with your advisor before each semester starts to review your course of study and revise it as necessary. Please feel free to discuss your proposed course plan with any of the faculty members; however, your primary advisor must formally approve your course plan.

Eventually you will select a faculty member to act as the **research supervisor** for your MS report, MS thesis, or PhD dissertation. Your research supervisor need not necessarily be the same individual as your academic advisor; choice of a research supervisor can be made later. At this later time, you and your research advisor will also select a graduate committee for your degree examination.

## **1.2 To Do Right Away**

### **Establish Colorado Residency**

If you are a US citizen or permanent resident and have come from out of state, you should, as soon as possible, take steps to establish Colorado residency. This includes obtaining a Colorado driver's license, registering your car in Colorado, and registering to vote in Colorado. Establishing residency qualifies you for much lower in-state tuition after 12 months.

### **Activate IdentiKey**

There are many computer resources on campus and in the department and you should immediately sign-up for a computing account. An IdentiKey is created when you are admitted to the University of Colorado Boulder by the university's student information system. After being accepted, you may activate your IdentiKey. Details can be found at: <http://www.colorado.edu/oit/services/identity-access-management/identikkey>. You need your IdentiKey for various campus accounts and resources.

### **Obtain Lab Access**

The Office of Information Technology also manages some computer resources through the Bechtel Lab in the Civil Engineering wing of the Engineering Center (ECCE). The Lab is used for upper division and graduate coursework and you can use your IdentiKey to log in. It is also valuable to establish an account in the Integrated Teaching and Learning Laboratory (ITLL), which is across the enclosed bridge at the end of the ECCE wing. Account arrangements can be made through the ITLL main office.

You can access the Bechtel Lab via a card reader which reads your BuffOne card. To obtain the access, send a picture of your BuffOne card to CEAE office [CEAEOffice@colorado.edu](mailto:CEAEOffice@colorado.edu). Please send the email from your Colorado.edu address and indicate reasons for your request (courses, etc.).

### **Join AREN Listserv**

We have established a listserv for Architectural Engineering (AREN) colleagues. This list is used for various announcements (including job, internship, and TA/RA positions). It is very important that you subscribe to this email list by sending an email to [sympa@lists.colorado.edu](mailto:sympa@lists.colorado.edu) with the following line in the message body (where Your Name is your real name):

subscribe ceae-bsp Your Name

## 2. PROGRAM OF STUDY

Your overall course of study must be discussed with and approved by your academic advisor within the first week of the first semester. You are also strongly encouraged to review the course plan with your advisor at the beginning of every following semester. This will avoid any surprises during the semester that you are trying to graduate. Your course of study may be wide or narrow; it will depend on your personal career plans. People who are thinking of a future in research work may take a different approach than those who see themselves working in industry for a design or consulting engineering firm. However, your advisor will ensure that you do end up with a good grounding in all aspects of architectural engineering. Your program of study may be modified at any time (in consultation with your advisor); however, you should always have an overall plan on file.

### Program Pre-requisites

It is expected that AREN graduate students will have a solid background in Engineering. Students with an MS degree in Engineering are considered to meet our prerequisites. Students without an MS degree in Engineering should meet the following **undergraduate pre-requisite courses**:

1. Ordinary Differential Equations
2. Physics I or Physics II
3. Thermodynamics
4. Any other pre-requisite courses identified by the academic advisor

All deficiencies must be completed before a graduate degree is awarded.

The make-up courses taken at CU to address deficiencies **will not count** toward the credit requirement for your graduate degree. **Up to two courses (6 credit hours) at the 3000 level** and above can be taken for graduate credit by doing extra work and by enrolling in them as independent studies. However, this can only be done with the agreement of the course instructor. Note that you are allowed a **maximum of 6 credit hours of "independent study"** in your degree.

### Program Requirements

The AREN graduate curricula will comprise a common core of required courses plus a set of courses specific to a track within each discipline. Students must select one of the four areas of specialization.

- All AREN graduates are expected to have a fundamental understanding of building systems, construction engineering, and sustainable building design. Students who lack sufficient exposure to the engineering of building mechanical and electrical systems, including lighting engineering, will be required to take a leveling course AREN 5001: Building Energy Systems, which is a prerequisite course for several BSE courses (and thus often suggested for the first semester). Note: BS/MS students are **not required** to take this course.
- In addition to these required courses, PhD students will also be required to take at least one course in applied mathematics or numerical methods as suggested by your advisor.

There are also courses in other departments that will be of value, for example undergraduate-level courses offered in some of the architectural engineering areas may be useful for you to take prior to, or instead of, the graduate-level courses. If you wish to gain registration as a Professional Engineer but do not have a BS in engineering from an ABET-accredited engineering program, please consult the Colorado Board of Registration (<http://cdn.colorado.gov/cs/Satellite/DORA-Reg/CBON/DORA/1251632130538>) for more details about the current rules.

### 3. ARCHITECTURAL ENGINEERING PROGRAM AREAS

Courses offered in the Architectural Engineering Graduate Program include various disciplines and focus areas related to building systems engineering, one specific to the CEM discipline and three are related to the BSE discipline. After taking the core course (AREN 5001 Building Energy Systems), students can enroll in any set of courses from different focus areas after consultation with their academic advisor(s). *Must complete a minimum of 9 credit hours from the list of courses.* The specific course and examination requirements for both MS and PhD degrees are outlined in Section 4.

The course offerings are categorized into four focus areas specific to building systems as well as courses specific to the Engineering for Development Communities (EDC) certificate.

#### **Core Course (required for all students with no AREN undergraduate degrees)**

- AREN 5001 – Building Energy Systems

#### **General Courses (suitable for any focus area)**

- AREN 5890 – Sustainable Building Design
- AREN 5990 – CFD for Built and Natural Environments
- AREN 5830 – Special Topics: Building Systems Modeling and Simulation
- AREN 5030 – Data Science for Energy and Buildings
- CVEN 5836 – Construction Engineering Fundamentals

#### **Building Energy Engineering**

- AREN 5010 – HVAC System Modeling and Control
- AREN 5110 – HVAC System Design
- AREN 5060 – Electrical Distributed Generation
- AREN 5080 – Computer Simulation of Building Energy Systems
- AREN 5020 – Building Energy Audits
- CVEN 5830 – Special Topics: Grid Connected Systems
- CVEN 5830 – Special Topics: Modeling and Simulation of Community Energy Systems
- ECEN 5007 – Power Systems Planning and Optimizations
- ECEN 5007 – Renewable Energy: Future of Power Grid
- ECEN 5007 – Data Analytics and Decision Making for Power Systems
- AREN 5570 – Electrical Systems

#### **Illumination Engineering**

- AREN 4550 – Illumination II\*
- AREN 5130 – Optical Design
- AREN 5830 – Luminous Radiative Transfer
- AREN 5580 – Daylighting
- AREN 5830 – Advanced Lighting Design
- AREN 5620 – Adaptive Lighting Systems

*\*Must enroll in CVEN 5849: Independent Study to receive graduate credit for this course.*

*Note: BS/MS students in Lighting, please consult with Jennifer Scheib regarding MS coursework.*

#### **Materials and Resources**

- AREN 5650 – Forensic Engineering
- CVEN 4565 – Design of Wood Structures\*

- AREN 4315 – Reinforced Masonry Design\* (spring only, every other year)
- AREN 5660 – Embodied Carbon in Buildings
- CVEN 5831 – Construction Materials

\*Must enroll in CVEN 5849: Independent Study to receive graduate credit for this course.

### ***Construction Engineering and Management***

- CVEN 5246 – Legal Aspects of Construction
- CVEN 5276 – Engineering Risk and Decision Analysis
- CVEN 5226 – Construction Safety
- CVEN 5346 – Managing Projects and Organizations
- CVEN 5836 – Infrastructure Asset Management

### ***Engineering for Developing Communities Certificate***

Students admitted to the Engineering for Developing Communities (EDC) certificate program must fulfill the coursework and practicum requirements of that program. For AREN students, up to six (6) units of the required EDC coursework can count as coursework needed for the MS/PhD degree. Please speak with Prof. Wil Srubar for more information.

**PLEASE NOTE:** Some of the above listed courses are not offered every year as research-active faculty are only required to teach a limited number of courses per year. For many faculty members who are required to offer undergraduate courses each year, the main implication of this policy is that graduate courses will be offered with less regularity. However, since most students take two years to complete their studies, all courses should be available to you with a good planning.

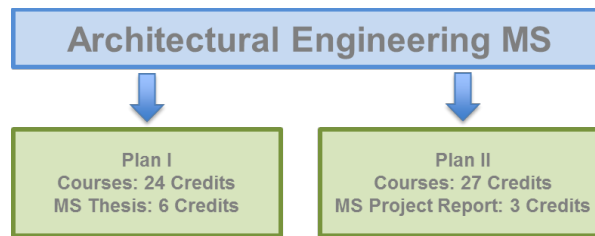
## **4. ARCHITECTURAL ENGINEERING PROGRAM DEGREES**

### ***4.1 Master of Science Degree in Architectural Engineering***

For a Master of Science (MS) degree in Architectural Engineering, the student may undertake "Plan I" with a thesis or "Plan II" with a project. Plan I requires 24 credit hours of course work plus 6 credit hours of MS Thesis work, while Plan II requires 27 credit hours of course work plus 3 credit hours of MS Project work. The MS Thesis is a formal research document that discusses a research topic with a significant amount of novelty and scientific exploration. Experience has shown that it takes a typical student from 24 to 30 months to complete Plan I. Financial support is generally limited to exceptionally well-qualified students selecting Plan I. Students pursuing Plan II will prepare an MS Report, which tackles a more well-defined research question with more structure and less exploration relative to the MS Thesis option. Experience has shown that it takes a typical student around 24 months to complete Plan II. AREN faculty believes that independent research constitutes a central part of a graduate university degree and a unique opportunity for strengthening engineering skills as well as providing a lasting contribution to the field.

Students entering with a desire to exclusively add graduate level coursework without an interest in scholarly work and scientific inquiry are directed to the Professional MS outlined in its own advising guide.

AREN BS/MS students at UCB can take the coursework only option by completing 30 credit hours of course work. BS/MS students should consult with their academic advisor for details.



Note that one half of the course work must be taken in the CEAE Department (An exception may be made if the relevant courses were taken as part of an undergraduate degree). Non-CEAE courses at the 4000 level may be used for graduate credits up to a maximum of 6 credit hours, with the approval of the advisor(s).

Up to 6 credit hours of "independent study" may be taken where an individual course of study is worked out between the student and a faculty member. Up to 9 credit hours of graduate courses can be transferred from another institution. Students are allowed up to 6 credit hours in total of non-technical coursework for the MS/PhD degree.

#### ***4.2 Doctor of Philosophy Degree in Architectural Engineering***

For a Doctor of Philosophy degree (PhD) in Architectural Engineering, you need at least 30 credit hours of graduate-level coursework plus a dissertation. For students with a MS degree from another university, up to 21 hours of acceptable graduate courses may be transferred leaving at least 9 credit hours of coursework to be done at the University of Colorado, if approved by their advisor(s). The transfer credits are transferrable at the discretion of the research advisor and students may be asked to take additional courses towards the completion of their degree. Work already applied toward a graduate degree received from CU or another institution cannot be accepted for transfer toward another graduate degree of the same level at CU. All courses accepted for transfer must be graduate-level courses. A course in which a grade of B- or lower was received will not be accepted for transfer. Please consult the CEAE Graduate Advisor for the procedure and most updated rules.

For students already in the MS program in the CEAE department, 30 credit hours of graduate coursework performed at CU is applicable towards the PhD degree upon the approval of their advisors. The PhD also requires that 30 hours of dissertation credit be taken with a **minimum residency** of 2 years. After passing the Comprehensive Exam, PhD candidates are required to maintain continuous registration. Candidates must register for at least 5 hours of dissertation credits each semester.

## **5. SIGNIFICANT MILESTONES**

Significant milestones along the pathway toward your MS or PhD degree are:

- (1) For a Master of Science degree, you will take a **Final Exam** at the end of your studies. If you choose the thesis or report option, your final exam is, in part, an oral defense of your thesis or report.

For Plan I, the students are required to submit to all members of their committee at least one week before the final examination date, a thesis report formatted according to the University of Colorado Graduate School specifications and a technical paper suitable for publication in a refereed journal.

For Plan II, the students are required to submit to all members of their committee at least one week before the final examination date, a project report and a technical paper suitable for publication in peer-reviewed conference proceedings.

- (2) For a PhD you will have a **Preliminary Exam**, taken in the first two years of your studies. This exam is given to test your background knowledge and diagnose areas for further study. You will also have a **Comprehensive Exam**, taken after coursework is completed and at the beginning of research work on the dissertation. Candidacy requires passing the comprehensive exam. Your **Final Exam** is the defense of your dissertation.



PhD students are required to submit to all members of their committee at least **two weeks** before the final examination date, a dissertation report formatted according to the University of Colorado Graduate School specifications. They are also required to have at least one technical paper be submitted AND accepted for publication in a refereed journal.

### 5.1 Master's Degree Final Exam

The MS **Final Exam** is taken after both coursework and the report/thesis are completed. The exam is an oral exam of at least two hours in duration if you have chosen the thesis or report option. It is your responsibility to arrange the schedule for the exam and to complete the Departmental and Graduate School forms associated with it. The first part of the exam is open to the public, and starts with a 45-minute presentation of the work undertaken for the report or thesis. The remainder of the first part includes a discussion of this work, including questions from the committee and general public.

The meeting is then closed to the public. The committee examines the candidate on any appropriate engineering topic. This examination will be based on, but not limited to, the graduate coursework and the research quality and quantity.

The thesis or report is prepared in consultation with the student's research advisor(s). The candidate is expected to supply to the committee members, at least one week before the exam, a complete copy of the final draft of the report or thesis and a draft of a technical paper suitable for publication in a peer-reviewed conference proceedings for the report option or a peer-reviewed journal for the MS thesis option. Incomplete or late drafts will result in cancellation of the exam.

### 5.2 PhD Preliminary Exam

The PhD Preliminary Exam should be scheduled in the first two years following admission to the PhD program. The exam is designed to test the candidate's general background knowledge. It is also partly a diagnostic exam to identify areas of weakness. The exam will usually be given during the first weekend of the Fall semester. Students must register for the exam with the AREN Graduate Officer before taking the exam. Students must select the AREN-related topics during the registration.

The exam will be a day-long written exam in which the candidate may be questioned on the following engineering topic. **Students must receive 75% to pass the exam.** A student who fails the Preliminary Exam is suspended from the program and will be eligible for *one* make-up exam.

#### Fundamental Topics (60%):

##### Required (20%)

- Mathematics (20%): within the scope of *APPM 2360 Introduction to Linear Algebra and Differential Equations*

Selective (40%): Select 2 topics from the list of topics

- Thermodynamics (20%): within the scope of AREN 2110 Thermodynamics
- Heat Transfer (20%): within the scope of AREN 2120 *Fluid Mechanics and Heat Transfer*
- Fluid Mechanics (20%): within the scope of AREN 2120 *Fluid Mechanics and Heat Transfer*
- Statics (20%): within the scope of CVEN 2121 *Analytical Mechanics*

#### AREN-related Topics (40%):

Select only 2 topics from the list of topics:

- HVAC Fundamentals (20%): within the scope of AREN 5001 *Building Energy Systems*
- Electrical Fundamentals for Buildings (20%): within the scope of AREN 5001 *Building Energy Systems*
- Illumination Fundamentals (20%): within the scope of AREN 5001 *Building Energy Systems*
- Construction Engineering and Management Fundamentals (20%): within the scope of CVEN 5836 *Construction Engineering and Management*
- Materials and Resources (20%): within the scope of AREN 5001 *Building Energy Systems*

### **5.3 PhD Comprehensive Exam**

The **Comprehensive Exam** is an oral exam taken by a PhD candidate after coursework is completed and at the beginning of substantial dissertation work. The oral exam usually lasts approximately two hours, covering both a presentation and discussion of your research plan as well as an examination of the underlying engineering foundations. It is your responsibility to arrange the schedule for the exam and to complete the Departmental and Graduate School forms associated with it. During the oral exam, the candidate is expected to present a proposal to the PhD dissertation committee and answer specific questions about fundamental analysis methods and the proposed evaluation approach. A written proposal should be provided to each committee member at least one week prior to the oral exam. The proposal typically includes a statement of the problem and research objectives, a review of the literature, a description of preliminary work and results, and a planned research agenda. The committee may approve the proposal at the time of the presentation or ask that the proposal be developed more fully.

### **5.4 PhD Final Exam**

Similar to the MS degree, the PhD **Final Exam** is taken after the dissertation has been completed. The exam is an oral exam of at least two hours in duration. It is your responsibility to arrange the schedule for the exam and to complete the Departmental and Graduate School forms associated with it. The first part of the exam is open to the public, and starts with a 45-minute presentation of the work undertaken for the dissertation. The remainder of the first part is taken up with discussion of this work including questions from the committee and general public. The meeting is then closed to the public. The committee examines the candidate on any appropriate engineering topic. This examination will be based on, but not limited to, the graduate coursework and the research quality and quantity.

### **5.5 Fundamental Expectations of AREN Graduates**

Upon graduation, you will hold an advanced degree in architectural engineering, which carries with it fundamental expectations about your assimilated knowledge. During the MS Degree Final Examination or the PhD Comprehensive Examination, you should be able to correctly answer fundamental questions on the following topics (as they pertain to your particular course of study): Thermodynamics, Heat Transfer, Construction Materials, Structural Engineering, HVAC Systems, Electrical Systems, Illumination Fundamentals, Mathematics (Calculus, Differential Equations, Numerical Methods), Construction Engineering, and Project Management.