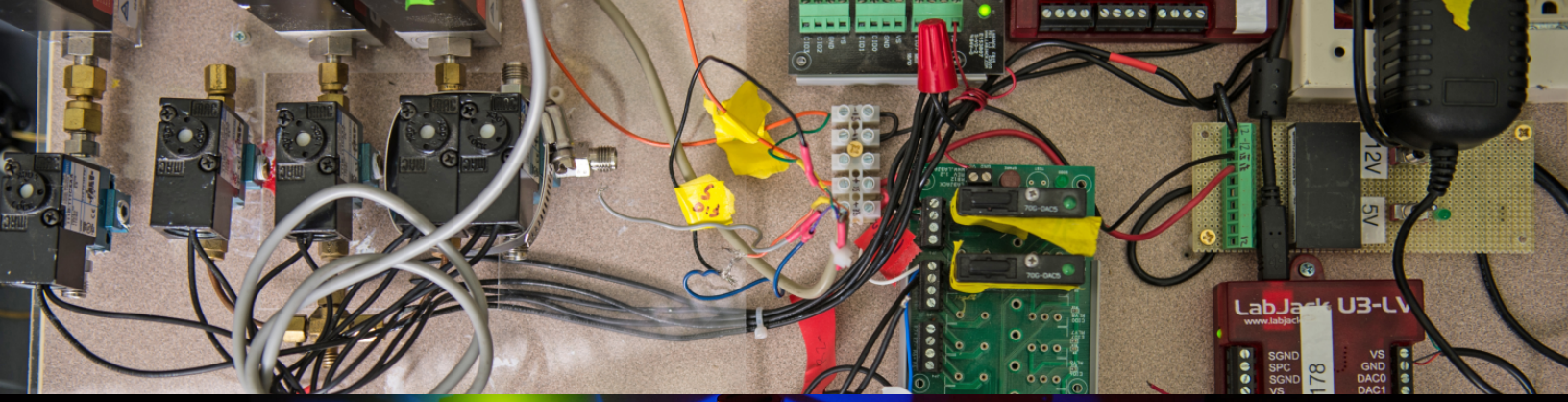
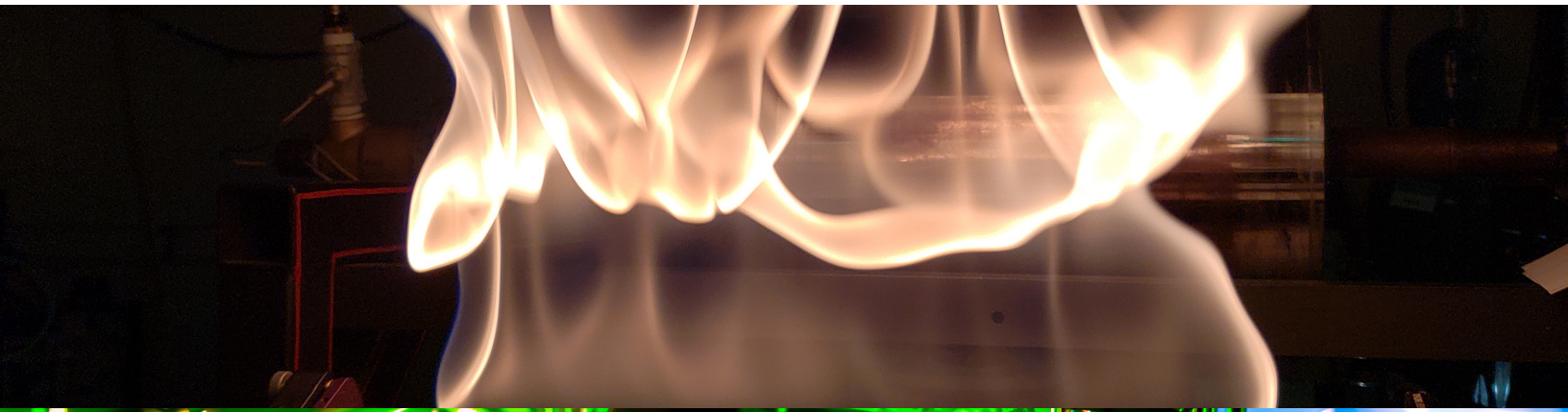


Paul M. Rady Department of Mechanical Engineering
Graduate Program Handbook

University of Colorado, Boulder

2021-2022 Academic Year



PAUL M. RADY DEPARTMENT OF MECHANICAL ENGINEERING
GRADUATE PROGRAM HANDBOOK

UNIVERSITY OF COLORADO, BOULDER

2021-2022 ACADEMIC YEAR

LAST UPDATED: MAY 17, 2022

Contents

1 Graduate Program Overview

1.1 Department Vision

The Department of Mechanical Engineering at the University of Colorado, Boulder (CU) will develop new scientific understanding, launch innovative technologies, and nurture creative engineers who will solve pressing societal challenges to improve health, enhance security, and create a clean and sustainable energy future. Faculty, students, and staff in the department seek to:

- **Be known for high-impact research:** Our faculty are internationally known for strengths in biomedical engineering, renewable and sustainable energy, and materials innovation. We plan to build that same prominence in soft robotics, imaging complex media, and quantum technologies. Our faculty and students will continue to publish in high-impact journals, spin off technology companies, become future faculty, and serve on national advisory boards.
- **Be a national leader in project-based education:** Project-based learning improves training for the practice of engineering, and project-based education provides the best opportunity to connect research and educational activities. Specifically, we will establish our leadership through faculty and student fellowships and awards.
- **Be a national leader in inclusive excellence:** Research shows that diversity in engineering teams and in companies leads to more innovative and successful outcomes. We feel strongly that we all deserve the opportunity to be global leaders in engineering.
- **Support engaged scholarship, an innovative spirit, and a collaborative community including alumni:** Our faculty are recognized nationally and internationally, and our students go on to successful careers in industry, academic, and the public sector. We seek to broaden the impact of our program through outreach and to also maintain close connections with our alumni so that we can be as responsive as possible to current trends in hiring, research, and instruction.

1.2 Graduate Program Mission Statement

The CU mechanical engineering graduate program supports the department vision by establishing an environment of respect and inclusive excellence where high-quality instruction, project-based learning, and cutting-edge research are leveraged to educate and nurture the next generation of socially conscious, deeply knowledgeable engineers, scientists, and problem-solvers. We are uncompromising in our belief that respect, inclusiveness, accountability, community engagement, honesty, and a commitment to excellence are the core values of any successful graduate program. These are the values that we work to continuously promote in students,

faculty, and staff, so that our graduates become our greatest ambassadors.

1.3 Degree Programs

With nearly 60 research and instructional faculty members, listed here, our graduate students have access to dynamic and interdisciplinary research and courses within our PhD, master's degree, and certificate programs.

- **PhD Program:** Mechanical engineering PhD students at CU take part in cutting-edge, tier-one research, learning from nationally and internationally recognized faculty. Our research harnesses state-of-the-art experimental, theoretical, and computational approaches to expand the frontiers of technology, while advancing fundamentals in a wide range of disciplines.
- **Master's Degree Programs:** Mechanical engineering master's degree students can take graduate courses and participate in research as part of four different programs.
  - *Master of Science (MS) Professional Program:* The MS Professional Program is our most popular master's degree option, offering exciting opportunities for a wide range of prospective students from diverse backgrounds. It emphasizes project-based and curriculum-driven learning and is targeted at working engineers and undergraduates considering a career in industry.
  - *Master of Science (MS) Thesis Program:* The MS Thesis Program is intended for MS students interested in a short-term research experience, leading to the preparation and defense of a research-based thesis. The program emphasizes education through high-quality research for students interested in careers in industry and the public sector.
  - *Bachelor's Accelerated Master's (BAM) Program:* The BAM degree program offers currently enrolled CU mechanical engineering undergraduate students the opportunity to receive bachelor's and master's degrees in a shorter period of time.
  - *Joint Mechanical and Environmental Engineering BAM Degree Program:* The mission of this joint BAM degree is to equip students with advanced understanding of principles in environmental science, environmental engineering and mechanical engineering. Students earn a bachelor's degree in environmental engineering and a master's degree in mechanical engineering.
  - *Dual Degree Mechanical Engineering and Engineering Management Program:* Students in the MS Professional Program may apply for a dual degree in Engineering Management. This program is intended for students seeking a strong education in both technical and fundamental topics, as well as the unique skills required to be a successful leader in industry and the public sector.
- **Certificate Programs:** Either degree-seeking or non-degree-seeking students can enroll in three or four course certificate programs offered by our department. These certificates indicate expertise in a focused topic area and are intended primarily for continuing education and non-traditional students, though they can be pursued as a supplement to the master's or PhD curricula.

1.4 Contact Information and Personnel

The Department of Mechanical Engineering is located in the Engineering Center at CU, with the following physical and mailing addresses:

Physical address (map):	**Mailing address:**
1111 Engineering Drive	427 UCB
Boulder, CO 80309	Boulder, CO 80309-0427

Overall administration of the graduate program, review of applications, and admissions decisions are handled by the graduate committee. This committee consists of roughly ten current members of our faculty, as well as our lead graduate teaching fellow, a representative from the Committee for Equity in Mechanical Engineering (CEME) and two graduate student representatives from the PhD and master's degree program.s Faculty on the graduate committee change from year to year and represent a range of different research and educational areas in our department.

During the 2021-2022 academic year, Prof. Peter Hamlington will serve as Graduate Program Chair, Ms. Vera

Sebulsky will be the Senior Graduate Advisor responsible for program administration and admissions, and Ms. Anna Guy will be the Graduate Advisor responsible for academic advising. Mr. Zach Irwin will serve as the Lead Graduate Student Teaching Fellow.

Dr. Daven Henze
Professor, Graduate Program Chair
Email: daven.henze@colorado.edu
Telephone: 303-492-8716
Room: ECME 265

Ms. Vera Sebulsky
Senior Graduate Advisor for Program Administration and Admissions
Email: vera.sebulsky@colorado.edu
Telephone: 303-492-4717
Room: ECME 105

Ms. Anna Guy
Graduate Advisor for Academic Advising
Email: anna.guy@colorado.edu
Telephone: 303-735-6346
Room: ECME 105A

Mr. Zach Irwin
Lead Graduate Student Teaching Fellow
Email: zachariah.irwin@colorado.edu

If you have a question and are not sure who to contact, you can also email megrad@colorado.edu and will receive a prompt reply.

1.5 Student Expectations and Policies

A complete list of CU student, faculty, and staff policies, to which the mechanical engineering graduate program rigorously adheres, can be found here. Graduate school policies are available here and a more comprehensive list of campus policies is available here. Select expectations and policies of greatest relevance to mechanical engineering graduate students are provided in the following sections.

1.5.1 Honor Code Policy

All students of CU are responsible for knowing and adhering to the academic integrity policy. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic and non-academic sanctions (including but not limited to university probation, suspension, or expulsion).

The University Honor Code and Procedures are accessible via the Student Conduct and Conflict Resolution website and can be viewed here. All Department of Mechanical Engineering graduate students are expected to adhere to this code.

1.5.2 Classroom Behavior Policy

Students and faculty each have a responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color,

culture, religion, creed, politics, veteran status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to instructors with the student's legal name, but instructors will honor student requests to address them by an alternate name or gender pronoun. Students should advise instructors of this preference early in the semester so that they may make appropriate changes to their records. Additional policy details are available here.

1.5.3 Discrimination and Harassment Policy

CU is committed to providing an inclusive environment where all individuals can achieve their academic and professional aspirations free from discrimination, harassment, and/or related retaliation based upon protected classes.

CU prohibits discrimination and harassment on the basis of protected-class status in admission and access to, and treatment and employment in, its educational programs and activities. For purposes of this CU policy, "protected classes" refers to race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation, and political philosophy.

CU takes prompt and effective steps reasonably intended to stop any form of protected-class discrimination and harassment, and related violations, to eliminate any hostile environment, to prevent its recurrence, and as appropriate, to remedy its effects.

At CU, the Office of Institutional Equity and Compliance (OIEC) implements this policy and administers related campus procedures. Anyone who encounters an issue or seeks guidance related to this policy should consult with the OIEC. CU Boulder employees who are mandatory reporters (i.e., "Responsible Employees"), including faculty and graduate advisors, must promptly report allegations of protected-class discrimination and harassment, and related violations, as further outlined in the policy.

The full university Discrimination and Harassment Policy can be viewed here.

Instructors are required to observe religious holidays for absences from class and exams, according to the policies outlined here.

1.6 Mental Health and Other Campus Resources

Students with a variety of concerns, such as academics, anxiety, body image, depression, relationships, substance use and more, should contact Counseling & Psychiatric Services (CAPS), which is a confidential, on-campus mental health and psychiatric service.

Counseling & Psychiatric Services (CAPS)
Website: https://www.colorado.edu/counseling/
Phone: 303-492-2277 (24/7 phone)
Location: Center for Community, N352
Office Hours

The Office of Victim Assistance (OVA) also provides free and confidential information, consultation, support, advocacy, and short term counseling services to CU students, graduate students, faculty and staff who have experienced a traumatic, disturbing or life disruptive event.

Office of Victim Assistance (OVA)
Website: https://www.colorado.edu/ova/
Email: assist@colorado.edu
Phone: 303-492-8855 (24/7 phone); after hours press 2 to talk to a counselor
Location: Center for Community, N450
Office Hours

Additional campus resources can be found here and more general health resources are available here.

1.7 Grievance Procedures

The Graduate School established revised grievance procedures, effective April 1, 2019, that can be found here: Graduate School Grievance Procedures. These procedures are intended to provide a process by which graduate students can communicate concerns related to academic issues or academic conflicts. An additional brief guide is available here. Should a student need any assistance with these procedures, they should reach out to their Graduate and/or Faculty advisor, where appropriate.

1.8 Departmental Staff Contacts

A comprehensive list of the financial, advising, communications, human resources (HR), and facilities staff members available to help faculty and students in our department can be found here: Staff Directory. Current staff members that students may frequently interact with are:

- Andy Garcia, Facilities Management Coordinator, andrew.garcia-3@colorado.edu
- Shirley Chessman, Idea Forge Mechanical Lab Engineer, shirley.chessman@colorado.edu
- America Palacios, Interim Finance Manager, america.palacios@colorado.edu
- Greg Potts, Laboratory Coordinator, greg.potts@colorado.edu
- Nur Daghestani, Temporary HR Coordinator, nur.daghestani@colorado.edu

If students are unsure about who can help them with a particular question or problem, they should email the graduate advisors at megrad@colorado.edu.

1.9 Academic Calendar and Registration Deadlines

Details on the 2021-2022 academic calendar can be found here. Additional information on course add/drop, tuition/fees, and registration deadlines is available from the Office of the Registrar. While the Graduate Program will make every effort to provide general reminders and information about important dates throughout the academic year, students are expected to be aware of any add/drop deadlines and tuition/fees impacts of their enrollment decisions. If you are unsure of the consequences of adding/dropping a course (especially outside of your university designated enrollment window), please reach out to megrad@colorado.edu.

1.10 Helpful Links

Additional resources and information of relevance to prospective and current mechanical engineering graduate students can be found at:

- **University Home Page:** https://www.colorado.edu
- **Graduate School:** https://www.colorado.edu/graduateschool/
- **College of Engineering:** https://www.colorado.edu/engineering/
- **Department of Mechanical Engineering:** https://www.colorado.edu/mechanical/
- **ME Department Calendar:** https://www.colorado.edu/mechanical/news-events/me-department-calendar
- **Buff OneCard:** https://www.colorado.edu/buffonecard/
- **Bursar's Office:** https://www.colorado.edu/bursar/
- **Campus Policies:** https://www.colorado.edu/policies/
- **Graduate School Catalog:** https://catalog.colorado.edu/graduate/
- **Medical Services:** https://www.colorado.edu/healthcenter/
- **Office of Information Technology:** https://oit.colorado.edu
- **Office of Institutional Equity and Compliance:** https://www.colorado.edu/oiec/
- **Office of the Registrar:** https://www.colorado.edu/registrar/
- **Parking and Transportation:** https://www.colorado.edu/pts/
- **Recreation Services:** https://www.colorado.edu/recreation/
- **Athletics:** https://cubuffs.com
- **Local News:** https://www.dailycamera.com
- **Elevations Credit Union:** https://www.elevationscu.com
- **Regional Transportation District (RTD):** https://www.rtd-denver.com

2 Admissions

2.1 Overview

In the Department of Mechanical Engineering, we have a diverse group of graduate students who benefit from—and directly support—an inclusive and supportive educational environment that emphasizes shared excellence. The admissions process plays a critical role in maintaining these values, and we seek to continue growing our graduate program by emphasizing diversity, participation by under-represented groups, community engagement, and technical excellence.

Graduate admissions decisions are made by a committee comprised of the graduate program chair, the graduate advisors, and faculty from the department. When making admissions decisions, this committee conducts a holistic review of all application materials, including the completed application form, grade point averages (GPAs) from prior undergraduate and graduate courses, and transcripts, as well as a statement of purpose, prior job and research experience, and recommendations from individuals who have had an opportunity to observe the ability and performance of the applicant. Although GPA is considered in admissions decisions, it is examined in the broader context of the entire application, also taking into account the quality of the undergraduate institution.

Consistent with our mission to create an inclusive environment, substantial consideration is given to special qualities such as student motivation, undergraduate program, initiative in research, professional engineering experience, diversity in economic, social, or cultural background, employment or other experience, leadership, and perseverance in overcoming personal handicaps or disadvantages.

2.2 Eligibility

2.2.1 PhD and Master's Degree Programs

To be eligible for either the PhD or master's (i.e., Professional MS or MS Thesis) degree programs, students must hold an undergraduate degree in engineering, sciences, or mathematics from an institution accredited by an agency recognized by the U.S. Department of Education. A complete list of accredited institutions and agencies is available from the Database of Accredited Post-Secondary Institutions and Programs.

Given the technical and quantitative nature of our graduate courses, any such degree should have included—or exceeded—the following course recommendations:

- Undergraduate courses in calculus, linear algebra, and differential equations;
- Two semesters of undergraduate calculus-based physics;

- At least two semesters of upper-division undergraduate courses in engineering or physics.

If an interested student has an undergraduate degree that does not cover these recommended courses, the graduate advising team should be consulted at megrad@colorado.edu prior to applying. If a student has completed prior graduate coursework or a graduate degree that addresses some or all of the above course recommendations, they are fully eligible to apply for either the PhD or master's degree programs, even if the undergraduate degree does not satisfy the recommendations.

Scores from either the general or subject graduate record examination (GRE) are not required or accepted as part of applications to the mechanical engineering graduate program. Note also that students do not need a master's degree to be admitted to the PhD program. Many of our PhD students enroll directly from their undergraduate institution with only a bachelor's degree.

Although we recognize that the GPA alone does not paint a complete picture of an applicant's prior performance and future potential, our most competitive applicants meet the following targets:

- **GPA:** For PhD applicants, the preferred undergraduate and graduate GPA is 3.4 or above, and for master's applicants the preferred undergraduate and graduate GPA is 3.2 or above.

International applicants are also required to take the Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS). Preferred scores for each of these tests are the following:

- **TOEFL:** The minimum required score is 80, but a score of 90 or above is preferred, particularly for PhD applicants seeking a Teaching Assistant (TA) position.
- **IELTS:** The minimum required score is 6.5, but a score of 7.5 or above is preferred, particularly for PhD applicants seeking a Teaching Assistant position.

The TOEFL/IELTS requirement is waived for international applicants for whom English is their native language, or who have completed at least one year of full-time study at a U.S. institution (or at an institution in a country where English is the native language), within two years from the desired admission term. The list of countries exempt from the TOEFL/IELTS requirement can be found here.

2.2.2 Provisional Admission

The CU Graduate School requires applicants to have a cumulative minimum GPA of 3.0 from prior undergraduate and graduate study in order to be accepted into either the PhD or master's degree programs on a non-provisional basis. Occasionally, applicants with below a 3.0 GPA who demonstrate exceptional credentials in the non-GPA components of the application may be offered admission on a provisional basis.

Further information for students admitted on a provisional basis is available here. To meet the standard terms of provisional admission, the student must complete 12 credit hours in two semesters at CU (or equivalent for part-time students) with a 3.00 cumulative GPA. Program faculty may recommend additional or alternative conditions as appropriate.

According to university policy, students admitted on a provisional basis are not eligible to hold an appointment (i.e., a teaching or research assistant position), without special permission, until they fulfill the specific conditions of their provisional admission. Consequently, the department cannot guarantee initial funding availability for applicants admitted on a provisional basis.

2.2.3 Bachelor's Accelerated Master's (BAM) Degree Program

Current CU mechanical engineering undergraduate students who meet the following criteria are eligible for admission to the BAM degree program in mechanical engineering:

- Must have a cumulative GPA of 3.25 or higher;
- Must have no Minimum Academic Preparation Standards (MAPS) deficiencies;
- Must have at least junior class standing;

- Must have completed four of the following six courses:
  - MCEN 3012: Thermodynamics
  - MCEN 3021: Fluid Mechanics
  - MCEN 3022: Heat Transfer
  - MCEN 3025: Component Design
  - MCEN 3030: Computational Methods
  - MCEN 3032: Thermodynamics 2

Students who plan to complete a double major(s) and/or minor(s) are also eligible for admission to the BAM program. In such cases, in addition to the BAM Intent Form, students must submit the BAM Double Major/Minor Certification form, which can be obtained by emailing the graduate advisors at megrad@colorado.edu.

Undergraduate students in the partnership program between CU and Colorado Mesa University (CMU) can be admitted to the BAM degree program if they satisfy the requirements above (or equivalent), if their CU GPA is above 3.0, and if their combined CMU and CU GPA is above 3.25.

2.2.4 Joint Mechanical and Environmental Engineering BAM Degree Program

Any student actively enrolled in the Environmental Engineering B.S. degree program may consider pursuing the BAM degree program, with a master's degree in mechanical engineering, provided that the following requirements have been satisfied:

- Must have a cumulative GPA of 3.25 or higher;
- Must have no Minimum Academic Preparation Standards (MAPS) deficiencies;
- Must have at least junior class standing;
- Must have completed the following courses:
  - APPM 2360: Introduction to Differential Equations with Linear Algebra
  - Fluid Mechanics: This requirement may be fulfilled by completion of any one of the following courses:
    - CHEN 3200 (Chemical Engineering Fluid Mechanics);
    - CVEN 3313 (Fluid Mechanics);
    - GEEN 3853 (Fluid Mechanics for Engineers);
    - MCEN 3021 (Fluid Mechanics).
  - Thermodynamics: This requirement may be fulfilled by completion of any one of the following:
    - AREN 2110 (Thermodynamics);
    - CHEN 3320 (Chemical Engineering Thermodynamics);
    - GEEN 3852 (Thermodynamics for Engineers);
    - MCEN 3012 (Thermodynamics);
    - EVEN 3012 (Thermodynamics 1).

Students applying for the BAM program will be eligible to pursue a secondary major(s) and/or a minor(s) and/or certificate(s) at the undergraduate level.

2.2.5 Dual Degree Mechanical Engineering and Engineering Management Program

Students in the mechanical engineering Professional MS program are eligible to pursue a dual master's degree in Engineering Management. Engineering management requires an undergraduate degree in engineering and a 3.0 or higher GPA from a regionally accredited institution. For full eligibility requirements, please visit the Engineering Management prospective student page. Graduate students in Engineering Management are also eligible for admission to our master's degree program, provided that they meet the eligibility requirements outlined in Section 2.2.1.

2.3 Application Requirements

2.3.1 PhD and Master's Degree Programs

For students not currently enrolled as undergraduate or graduate students at CU who would like to be considered for the PhD or master's (i.e., Professional MS or MS Thesis) degree programs, the following items must be submitted (requirements and procedures are provided in Section 2.7 for internal applicants and current students seeking to change degree programs within the Department of Mechanical Engineering and/or CU):

- **Application:** An application must be completed through the official graduate school admissions website. Through this application, students can select the degree program to which they are applying (i.e., PhD or Professional MS), as well as the most relevant focus area (described in more detail for the PhD program in Chapter 4 and for master's degree programs in Chapter 5). Note that the MS Thesis program does not offer direct entry. Students interested in the MS Thesis program should apply to the MS Professional program. If admitted, students can formally switch to the thesis program upon securing a thesis advisor. Also, the choice of focus area is not binding and is intended primarily to assist with application review and balancing student numbers in different areas.
- **Application Fee:** An application fee of $60 for domestic and $80 for international applicants must be paid at the time of application. Additional information on application fee waivers is provided in Section 2.3.4.
- **Curriculum Vitae:** A complete academic curriculum vitae (CV) detailing prior education, work, and research experience, as well as honors, awards, publications, conference presentations, and community engagement and outreach activities, must be provided. Helpful guidelines on the creation of academic CVs have been compiled by Cornell University and the University of Illinois Urbana-Champaign.
- **Personal Statement:** A personal statement must be provided by each student that describes academic and research interests, prior research and professional experience, achievements, and/or additional information that the admissions committee should be aware of. Students applying for the PhD program, and those interested in the MS Thesis program, are encouraged to describe faculty and research groups with whom they are interested in pursuing research. The best personal statements tell a story and do not simply repeat information that can be found on the CV. Rather, the personal statement is where a student can outline their interests, future goals, and how their prior educational, research, and professional experiences have prepared and motivated them to pursue a graduate degree from CU. The specific prompt for the personal statement is the following:
  - *Please upload a document (maximum 2 pages) describing your past work in your proposed or allied fields of study, including but not limited to: non-course educational experiences, teaching, or other relevant employment; community service and outreach; participation in activities and initiatives related to diversity, equity, and inclusion; publications, theses, research in progress, and other scholarly activities; your plans for graduate study and a professional career.*
- **Transcripts:** Unofficial transcripts must be provided from coursework at all post-secondary institutions (including community college courses, courses taken for college credit during high school, and study abroad coursework, even if this coursework shows as transfer credit on another transcript). Applicants offered admission who choose to matriculate at CU will be required to provide official transcripts for all schools attended prior to the beginning of their first semester.
- **Recommendation Letters:** Three letters of recommendation must be included in the application. Names and contact information for recommendation letter writers are solicited as part of the online application process. The strongest letters come from instructors/professors, research advisors, work supervisors, and others who can provide detailed comments on the potential of the student to succeed in graduate-level engineering coursework and, for PhD and MS Thesis interested students, research. Letters of recommendation from those outside of academia and/or research, as well as instructors of classes where a student received a poor grade or made little impression, are unlikely to help an application. Letters from family members will not be considered.
- **TOEFL/IELTS Scores:** International students must submit either TOEFL or IELTS scores using the institution code 4841 for CU. This requirement is waived for international students who qualify under the following conditions: (a) the student's native language is English, or (b) the student has completed at

least one year of full-time study at a U.S. institution (or at an institution in a country where English is the native language), at the time of submission, or within two years from the desired admission term. The list of countries exempt from the TOEFL/IELTS requirement can be found here.

To receive full consideration, all required application materials (including recommendation letters, unofficial transcripts, and TOEFL/IELTS scores) must be received by the deadlines outlined in Section 2.4.

GRE scores (either general or subject) are not required or accepted as part of a graduate application.

Note that all applicants for master's degrees must initially apply to the Professional MS degree program; direct entry to the MS Thesis program is not offered as it requires a commitment from a research advisor, which typically occurs after a student has enrolled at CU. Additional information on finding a research advisor for both PhD and MS Thesis applicants is provided in Section 2.9.

We recognize that financial support is an important consideration for prospective PhD and master's degree students, and additional detail on offers of admission and funding options in our department is provided in Section 2.6 and in Chapter 3.

2.3.2 Bachelor's Accelerated Master's (BAM) Degree Programs

Eligible students based on the criteria outlined in Sections 2.2.3 and 2.2.4, including students in the CU/CMU partnership program, may apply to either the traditional BAM program or the joint mechanical and environmental BAM program by completing the BAM Intent Form. If a student plans to complete a double major, they should also submit the BAM Double Major/Minor Certification form, which can be obtained by emailing the graduate advisors at megrad@colorado.edu. All applications for admission to the BAM program will be promptly reviewed by the mechanical engineering graduate program staff in accordance with the requirements outlined in Sections 2.2.3 and 2.2.4.

2.3.3 Dual Degree Mechanical Engineering and Engineering Management Program

Students in the MS Program are eligible to apply for the dual degree in mechanical engineering and engineering management. Admission to the engineering management degree is determined by the Engineering Management department. Please visit the Engineering Management Program admissions website to learn more.

Current Engineering Management MS students interested in applying for an MS degree in mechanical engineering should consult the internal application procedures outlined in Section 2.7.

2.3.4 Application Fee Waivers

The mechanical engineering graduate program recognizes that the application fee may be a challenge for some applicants. Our program is committed to providing educational opportunities for a diverse range of applicants and strives to waive application fees whenever possible. Please do not hesitate to contact us at megrad@colorado.edu with any questions about the various fee waiver opportunities listed below.

1. Graduate School fee waivers are available for participants in the following programs. If you are affiliated with one of these programs, please email proof of your affiliation to gradadm@colorado.edu before you apply to receive a waiver.
   - AmeriCorps (currently serving)
   - Louis-Stokes Alliance for Minority Participation (LSAMP)
   - McNair Scholars Program
   - Minority Access to Research Careers (MARC) Scholars Program
   - Peace Corps (currently serving)
   - Post-baccalaureate Research Education Program (PREP)
   - Teach for America
   - Leadership Alliance
2. Members of the US military will receive an automatic application fee waiver from the graduate school upon submission of the application.

3. Domestic PhD candidates with a 3.4 or higher undergraduate GPA who apply for admission prior to November 15, 2021 will receive an automatic application fee waiver upon submission of the application.
4. Faculty members may request fee waivers for international PhD applicants by sending the name and application number of the international student to megrad@colorado.edu.
5. Fee waivers are available directly from the department for PhD or master's applicants who are not eligible for the Graduate School fee waiver (see above for requirements for the Graduate School fee waiver), who are a US citizen, US permanent resident, or DACA recipient, and meet any one of the following:
   - The application fee is a financial hardship.
   - The applicant is a first-generation college student.
   - The applicant is/was involved in any organization aimed at increasing access to higher education and/or improving the higher education experience for students from underrepresented backgrounds. Some examples of organizations that meet this requirement include:
     - National Society for Black Engineers (NSBE) members/participants;
     - Society of Hispanic Professional Engineers (SHPE);
     - TRiO program participant;
     - CU Boulder Guardian Scholars Program;
     - GEM Fellowship applicant;
     - Bill and Melinda Gates Millenium Scholars;
     - CU Boulder's SMART and/or STEM Routes program participant.
6. Fee waivers are available to any CU Boulder undergraduate student applying to the PhD program.
7. Fee waivers may be requested for applicants eligible for accommodations via the Americans with Disabilities Act (ADA). Please note that students who chose not to utilize accommodations they were eligible for while an undergraduate are still eligible for a fee waiver.

To request a fee waiver from the department, please email megrad@colorado.edu before you apply. No documentation or explanation of your eligibility is required. Being successful scientists requires that we behave ethically and trust our peers, mentors and mentees to do the same. In that spirit, we trust you to judge for yourself whether you fulfill these criteria.

2.4 Deadlines

2.4.1 PhD Degree Program

In general, our department accepts PhD applications from external (i.e., anyone not currently enrolled at CU) applicants for the fall term only. To receive full consideration, students should submit all application items noted in Section 2.3.1 by the following deadlines:

- **International applicants:** December 1, 2021
- **Domestic applicants:** December 15, 2021

Note that domestic PhD applicants with a 3.4 or higher undergraduate GPA who apply for admission prior to November 15, 2021 are eligible for an application fee waiver that is automatically applied at the time of application.

In limited cases, external PhD applications may be accepted and reviewed for the spring or summer semesters. Typically, these applicants are transfer students who have already identified a CU PhD advisor. In such instances, the graduate advising team should be consulted at megrad@colorado.edu prior to applying. Applicants in this scenario should plan to ensure submission of all required application documents as soon as possible and no later than one month prior to the anticipated semester of matriculation.

Requirements and procedures for internal (i.e., current CU student) applicants to the PhD program are provided in Section 2.7.

2.4.2 Master's Degree Programs

Master's degree applicants are welcome to apply for either a spring or fall semester start. To receive full consideration, all required application items (including recommendation letters, unofficial transcripts, and TOEFL or IELTS scores) must be submitted by the following deadlines for each term:

- **International applicants:** November 1, 2021 (for spring 2022) and February 15, 2022 (for fall 2022)
- **Domestic applicants:** November 1, 2021 (for spring 2022) and February 15, 2022 (for fall 2022)

Requirements and procedures for internal (i.e., currently enrolled CU student) applicants to the master's degree programs are provided in Section 2.7.

Note that direct entry into the MS Thesis program is not permitted. Students interested in the MS Thesis program should apply to the MS Professional program. Upon procuring a thesis advisor, students admitted to the MS Professional program can formally switch into the MS Thesis program.

2.4.3 Bachelor's Accelerated Master's (BAM) Degree Programs

Eligible students interested in applying to any of the BAM programs associated with mechanical engineering can do so throughout the calendar year via the BAM Intent Form. Submission of applications is recommended during either the fall or spring semesters of a student's junior year. Specific deadlines for submission of an application to the BAM program are as follows:

- September 25, 2021 for students graduating with their BS in fall 2021;
- January 27, 2022 for students graduating with their BS in spring 2022;
- February 24, 2022 for students graduating with their BS in summer 2022.

Applicants considering applying later in their undergraduate career should familiarize themselves with all deadlines and requirements for progressing from undergraduate to graduate status on the BAM website.

2.4.4 Dual Degree Mechanical Engineering and Engineering Management Program

Students currently in the Department of Mechanical Engineering who wish to pursue the dual degree with Engineering Management should reach out to Ms. Kendra Thibeault at kendra.thibeault@colorado.edu for guidance on any deadlines for application.

Students in the Engineering Management Department wishing to pursue the dual degree with mechanical engineering can reach out to the graduate advisors at megrad@colorado.edu with questions. Please also see Section 2.7 for further information on internal applications.

2.5 Recruiting Activities

2.5.1 Graduate Engineering Annual Research and Recruitment Symposium (GEARRS)

The Graduate Engineering Annual Research and Recruitment Symposium (GEARRS) is an annual event that provides an overview of current research within the Department of Mechanical Engineering for a select group of domestic prospective PhD students. This event, which is held annually on the CU campus, offers a platform for the exchange and development of new ideas among members of the Department, industry, and prospective students. Research presentations are delivered by current PhD students and cover a wide variety of topics that include thermofluid sciences, bioengineering, robotics & controls, materials, micro/nano systems, air quality, and environmental sciences. Additional details on GEARRS can be found at https://www.cugearrs.com/.

Prospective students at GEARRS have numerous opportunities to meet with faculty and current students, and attendance at GEARRS is an important step towards finding a potential research advisor. Note that not all students given financial offers will have selected a research group or advisor by the time of matriculation at CU; every year a number of PhD students enter our program and join research groups within their first semester.

Attendance at GEARRS is by invitation only; the Department covers hotel, food and local transportation costs, as well as up to $275 for airfare costs. During the 2021-2022 academic year, the event will be held in late February 2022; invitations will be sent out by late-January 2022. The event occurs over a three-day period and consists of presentations from faculty and current students, group meals, lab tours, individual meetings between

prospective students and faculty, and recreational activities in Boulder. Information for GEARRS 2022 will be posted, as available, here.

2.5.2 International PhD Applicants

International students are highly valued members of the research, educational, and cultural communities in our department. Although we do not cover travel costs for international PhD applicants to attend GEARRS in person, we are continuing our efforts to live-stream and record presentations at the event.

In order to facilitate one-on-one contact with potential faculty advisors, particularly strong international PhD applicants will be contacted by mid-January to arrange video meetings with at least one member of the graduate admissions committee. Subsequent video meetings with other members of our faculty are also common.

Most importantly, prospective international PhD applicants are afforded equal consideration to domestic applicants, with respect to both offers of admission and offers of financial support, and we make every effort to maintain high levels of contact with international students.

2.5.3 Master's Degree Program Visit Day

Each year, a select group of master's Degree Program applicants will be invited to campus for a recruiting event, usually in early March. Invited students will hear about course offerings and be given the opportunity to ask questions during panel discussions with faculty and current students. Those students interested in pursuing an MS Thesis degree will be given the opportunity to meet one-on-one or in small groups with potential faculty research advisors. A small amount of funding will be available to support travel and accommodations for the MS Visit Day, and this support can be requested at the time of invitation.

2.6 Offers of Admission and Funding

2.6.1 PhD Degree Program

Students applying to the PhD program will automatically be considered for funding as part of the admissions application process. The department is committed to funding PhD students throughout the course of their studies. As such, students offered admission can expect a funding offer that includes a stipend, tuition coverage, dental coverage, and 90% of university health insurance coverage for the first year.

If invited, domestic PhD applicants are strongly encouraged to attend GEARRS, and international PhD applicants are strongly encouraged to talk via video conference with a member of the admissions committee.

Funding offers in the first year of the PhD degree take the form of Teaching Assistant (TA), Research Assistant (RA) appointments, or mixed TA/RA appointments. All first-year TA appointments are supported by the department (referred to as "departmental funding") and typically span the duration of the first academic year (i.e., 9 months, from August 15 to May 15). RA appointments may be supported either by the department or by individual faculty with funding from research grants or externally sponsored projects. RA appointments typically span the duration of the first academic year as well.

A number of incoming and current students also hold external fellowships, for example the National Science Foundation (NSF) Graduate Research Fellowship. These students are considered "Fellowship" students. In many cases, this type of funding provides 3 years of support, and the department is committed to providing 1-2 years of additional funding for Fellowship students to complete their PhD degrees.

By the start of the first summer after enrollment, all PhD students are expected to be supported on RA appointments by funding from a research advisor, or by external fellowships. Although the specifics of funding beyond the first year may vary from one student to another, the department is committed to funding all PhD students who are making adequate progress towards their degrees for the duration of their studies. Gaps in PhD student funding after the first year are handled using the Application for Department Support, described in more detail in Section 3.9.

In addition to appointments, PhD students may receive supplementary fellowships from the department or

the College of Engineering as part of their funding offer. In most cases, these are one-time awards that can be used towards costs not covered by the TA/RA appointment, such as student fees and room and board costs. Additional detail on fellowships and other financial awards is provided in Chapter 3.

2.6.2 Master's Degree Programs

Generally, master's students are expected to self-fund their studies and, in nearly all cases, are admitted to the MS program with no offer of funding. Specifically, TA and RA funding from the department is reserved for PhD students, although a limited number of MS Thesis students may receive a TA or RA appointment through their research advisor. Such appointments are left to the discretion of the advisor and are not guaranteed even with acceptance or transfer into the MS Thesis program.

In accordance with Graduate School regulations, students in the Professional MS program are not eligible for RA or TA appointments. However, funding opportunities for Professional MS students do exist in the form of hourly employment.

Master's degree applicants are also eligible to receive some departmental scholarships and fellowships. Additional detail on scholarships, other financial awards and hourly employment is provided in Chapter 3.

2.6.3 Offer Acceptance Deadlines

The deadline for applicants to accept offers of admission and funding are:

- **PhD Degree Program:** April 15, 2022
- **Master's Degree Program:** December 1, 2021 (for spring 2022) and April 30, 2022 (for fall 2022)

Note that an offer of either admission or funding is only considered "accepted" if the enrollment deposit is paid, in full, by the above deadlines. If the deposit is not paid and no request for deferral has been made prior to the deadline, the offer will be considered as "declined" and will be rescinded by the department at its discretion.

2.6.4 Deferrals

Students who have accepted an offer of admission to either the PhD or master's programs may request a deferral of their admission for up to one year. Both PhD and MS students may request to defer their admission to either the following fall or spring semester. Deferral requests will be considered on a case-by-case basis and should be communicated by email to megrad@colorado.edu.

Note that students deferring an offer that includes financial support (e.g., a TA appointment) will be required to submit the admissions deposit in order to secure the offer for a future semester. Some sources of funding may not be deferred to future terms, including departmental scholarships. Applicants considering deferment should make sure to clarify the future availability of any funding offer.

2.7 Internal Applicants and Changes of Program

Current CU students, both inside and outside the department, can apply to either our master's or PhD degree programs by completing the Change of Program Form. After completing this form and satisfying the other requirements noted below, applications are reviewed in full by the graduate admissions committee. All candidates for admission, including internal applicants, are evaluated based on the same high standards of eligibility outlined in Section 2.3.

2.7.1 Transfers within the Department of Mechanical Engineering

Before initiating any program change process, we recommend that students and any faculty member they may be working with reach out to the graduate program directly at megrad@colorado.edu for guidance on these procedures. Requirements for each category of in-department program change are as follows:

- **From BS/BA to Professional MS, MS Thesis, or PhD:** All current CU undergraduate students, including those in mechanical engineering but not in the BAM program, are required to submit applications according to the requirements outlined in Section 2.3 and the deadlines outlined in Section 2.4.
- **From Professional MS (including BAM) to MS Thesis:** Current ME graduate students can be considered

for these program changes by completing the Change of Program Form. Submit the form by December 1 to request a spring semester start, April 1 to request a summer semester start and August 1 to request a fall semester start.

- **From MS Thesis to MS Professional:** Same as above.
- **From PhD to MS Professional or MS Thesis:** Same as above.
- **From BAM, Professional MS, or MS Thesis to PhD:** There are two paths by which current mechanical engineering graduate students may apply for transfer into the PhD program, depending on their interest in receiving departmental support as a TA/RA:
  - **With departmental funding:** Students seeking departmental funding must submit the Change of Program Form by January 15. Applications in this category are accepted only for a fall semester transfer. Students will be considered, in conjunction with all external candidates applying to the PhD program, for a full academic year TA or RA appointment.
  - **Without departmental funding:** For current graduate students not seeking departmental funding because they have a fellowship (e.g., NSF or NDSEG), have secured funding from a research advisor as an RA, or are self-supported, the Change of Program Form must be completed. For these students, the transfer into the PhD program can be requested for any semester. Submit the form by December 1 to request a spring semester start, April 1 to request a summer semester start and August 1 to request a fall semester start.

For all students transferring into the PhD program, the following items are required in order to submit the Change of Program Form:

- The name and contact information of a current member of the CU faculty (ideally in mechanical engineering) who can comment on the appropriateness of the change into the PhD program. In the case of students transferring into the PhD program without departmental funding, this letter should come from a research advisor who commits to supporting the student for the duration of the PhD.
- A two-page statement from the student outlining research interests, prior research and professional experiences, and reasons for pursuing a PhD degree.
- Unofficial transcripts from CU and all prior undergraduate and/or graduate institutions.
- A current copy of the student's CV. Helpful guidelines on the creation of academic CVs have been compiled by Cornell University and the University of Illinois Urbana-Champaign.

Note that BAM students are only eligible to transfer into the PhD program if they have already completed their undergraduate degree(s); additional requirements may be applicable as well.

Additionally, BAM students are prevented by university policy from counting any credits towards the PhD degree that were already applied towards both the undergraduate and master's degrees; therefore, additional coursework beyond the requirements for the master's degree will be required.

2.7.2 Transfers within CU

All current CU undergraduate students outside the Department of Mechanical Engineering, but not in the BS/MS or BAM programs, are required to submit applications according to the requirements outlined in Section 2.3 and the deadlines outlined in Section 2.4. Application fees are waived for these students.

For current graduate students in other departments at CU, transfers into either the master's or PhD degree programs can again be initiated by completing the Change of Program Form. Additionally, all such applicants are required to provide:

- The name and contact information of a current member of the CU faculty who can comment on the appropriateness of the change into the mechanical engineering graduate program. In the case of students transferring into the PhD program without departmental funding, this letter should come from a research advisor who commits to supporting the student for the duration of the PhD.

- A two-page statement from the student outlining reasons for pursuing a degree in mechanical engineering, as well as research interests and prior research and professional experience if the student seeks to transfer into the MS Thesis or PhD programs.
- Unofficial transcripts from CU and all prior undergraduate and/or graduate institutions.
- A current copy of the student's CV. Helpful guidelines on the creation of academic CVs have been compiled by Cornell University and the University of Illinois Urbana-Champaign.

Students requesting transfer into either 1) the MS program; or 2) the PhD program, without request for department funding (i.e., those with an external fellowship or funding secured directly from the Research Advisor), are eligible to transfer at the beginning of any semester. The Change of Program Form should be submitted by December 1 for requests to begin during the spring semester, April 1 for requests to begin during the summer semester, and by August 1 for requests to begin during the fall semester.

PhD applicants seeking department funding are only eligible for transfer beginning in a fall semester. In these cases, the form must be submitted by January 15 to be considered for transfer beginning the following fall semester. Students will be considered, in conjunction with all external candidates applying to the PhD program, for a full academic year TA or RA appointment.

Note that these procedures and requirements apply even to students who are changing from another PhD program at CU into the mechanical engineering PhD program.

As with in-department transfers, BAM students are only eligible to transfer into the PhD program if they have already completed their undergraduate degree(s); additional requirements may be applicable as well.

Additionally, BAM students are prevented by university policy from counting any credits towards the PhD degree that were already applied towards both the undergraduate and master's degrees; therefore, additional coursework beyond the requirements for the master's degree will be required.

2.8 Certificate, Non-Degree, and Continuing Education Programs

2.8.1 Mechanical Engineering Certificates

Current CU graduate students interested in any of the mechanical engineering certificates can apply at any time. The following application materials can be submitted to megrad@colorado.edu:

- **Statement of purpose:** 1 page explaining how the certificate will benefit your professional and/or personal interests.
- **Proof of undergraduate degree in engineering or related field:** Official transcripts for your undergraduate degree are on file and do not need to be submitted unless requested directly.
- **Letter of support:** Please have one professional supervisor or faculty member provide a letter of support for your admission to the certificate program. This can be submitted to megrad@colorado.edu directly by the letter author. Letter submissions from the student will not be accepted.

If you are not a current CU student and do not plan to pursue an MS or PhD program at CU, you will apply as a non-degree student, as outlined in Section 2.8.2. Further information on available certificate programs can be found in Section 6.4.

2.8.2 Non-Degree and Continuing Education

Students not currently enrolled as a degree-seeking student at CU may be eligible to pursue individual graduate coursework and/or a graduate level biomedical engineering certificate. For consideration, students should complete the Online Enrollment Application through the Office of Continuing Education.

2.9 Finding an Advisor

For PhD students, it is extremely helpful to begin your first semester having already picked a research advisor, or to secure one within the first month of classes. Students interested in the MS Thesis program can utilize the resources in the section, but should note that, in nearly all cases, a research advisor is not procured until after

matriculation. You can read more about our faculty and their various research interests here.

An excellent opportunity for applicants to meet with potential advisors is during the department's annual GEARRS recruiting event for PhD students and MS Visit Day for students interested in the MS Thesis program. If invited to attend, you will receive the opportunity to meet with faculty whose research interests you. We highly recommend identifying one to three advisors that you would enjoy working with and that are engaged in research that aligns with your interests. When you have identified advisors that you would like to work with, keep the conversations going even after your visit. Professors are happy to talk to prospective students on the phone, through Skype or by email.

Below are a few tips as you discover what research group is the best fit for you:

- Investigate many different advisors, but keep in mind that some lab websites are not up to date with the most current research, so make sure to email and ask professors about their current work.
- Ask for contact information of lab group members and get their input on the strengths and weaknesses of their lab.
- Ask about what your role as a lab member may look like.
- Share your long-term goal for your PhD, even if you haven't yet figured out how to accomplish that goal. Professors love to hear what you are passionate about.
- Ask questions! Remember it is just as important to find a lab culture that is a good fit for you as it is to find a research topic that is interesting. We recommend asking questions like the following to both faculty and current graduate students.

Questions to ask a potential advisor:

- Are you taking new students?
- What would my role as a lab member look like?
- How many graduate students and post docs are currently in the lab?
- How would you describe the lab culture?
- What makes someone a good fit for this group?
- How would you describe your advising style?
- How would you describe graduate school in general?
- Do you collaborate with other research groups on or off campus?
- Is there funding for the project that I am interested in?
- Do you expect your students to apply for external funding?
- How many years do graduate students in your lab typically TA?
- How often do you meet with your students?
- How often do students attend conferences?
- What professional development opportunities are there in the lab?
- How do you feel about students taking a summer to do an internship?

Questions to ask other graduate students in the lab:

- Is the PI accessible?
- How would you characterize the PI's advising style (e.g. hands on, hands off)?
- Does the lab group do any activities together throughout the year?
- What are other student's technical backgrounds?
- What makes someone a good fit for this lab?
- How did you decide to join this lab?
- What do you like most about working in this lab group?
- Are there aspects of this group culture that you wish you could change?

3 Tuition, Fees, and Funding

3.1 Overview

We recognize that the cost of studying and living in Boulder is an important consideration for students of all levels. Although tuition and fees are set by the university, in the department we attempt to provide as much financial support as possible for our graduate students. This support includes multi-year teaching and research assistant (TA and RA, respectively) appointments, hourly employment opportunities, and travel grants for students giving presentations at conferences. Through these funding opportunities, we attempt to promote educational and research excellence, diversity, and community, while ensuring that graduate students are able to complete their degrees without undue or unforeseen financial burden.

3.2 Tuition and Fees

Because tuition and fees are charged at variable rates based on residency, program, student status, and number of enrolled credits each semester, a good understanding of the structure of tuition and fees can help to maximize the return on educational investment.

Detailed information on tuition and fees is available at this section of the CU Bursar's Office website. After choosing the appropriate semester on this page, PhD and MS Thesis student tuition rates are listed under the "Graduate" heading, while MS Professional tuition rates are listed under the "Professional Graduate" heading.

Fees are determined based on a number of factors. To determine the fees for which you are responsible, first identify your graduate status on the Graduate School website. Then, a full list of mandatory fees, by graduate status, can be found on on the fees section of the Bursar's Office website.

Important tuition and fee policies to note are:

- Fees accompany even 1 credit hour of tuition and should be taken into account when calculating educational costs.
- New domestic PhD students, including current CU students switching into the PhD program, are required to establish Colorado residency within 1 year of starting the PhD program. Further details on the requirements to establish residency are provided in Section 3.3.
- Students must be enrolled in classes during the first semester in which they enter a new degree program, requiring the payment of tuition and fees. For this reason, it is uncommon (although not impossible) for students to start new degree programs during summer terms.

Further questions about tuition and fees can be directed to the graduate advisors at megrad@colorado.edu.

3.3 Establishing Residency

New domestic PhD students who are not already Colorado residents must establish residency prior to the beginning of their second year. Any student wishing to establish Colorado Residency, including MS students, should take action immediately. Instructions on how to do establish residency are available from the Registrar's Office. Additional residency guidelines are available here. It takes exactly one year to gain residency and residency status may affect the possibility of future funding opportunities. Students should plan to complete the residency petition in their second semester.

3.4 Funding Overview

3.4.1 PhD Students

New 1st year PhD students are often funded by the department via TA or RA appointments, with PhD students in their second year and beyond typically funded by their research advisor(s) as an RA through support from sponsored projects, research grants, and contracts. University policy requires appointments for all graduate students be administered on a semester-by-semester basis. As such, if students have any questions about future funding, we encourage them to discuss plans with their faculty research advisor early each semester. Additional questions regarding funding can be directed to either the graduate advisors at megrad@colorado.edu or the graduate program chair.

In cases where funding for a current PhD student has not been secured or is not possible via other sources, the research advisor can apply for departmental support on the student's behalf. The Application for Departmental Support is available to faculty each semester, including summer. The Graduate Committee reviews applications for departmental support with consideration for availability of funds, previous history of departmental support for the student and the faculty member's financial need. Further detail on this application process is provided in Section 3.9.

3.4.2 Master's Degree Students

Students admitted to the master's degree program, including BAM students, are expected to secure their own financial support. Although the department does offer a number of scholarship opportunities, detailed in Section 3.6, recipients will still be expected to cover the majority of their cost of attendance either independently or via external sources. Scholarship application requirements and timelines may vary, but will be marketed through the departmental e-mail listserv for current graduate students, as well as on the departmental website.

While MS Thesis students are eligible for TA and RA appointments, these opportunities are very rare. There is no formal application process for MS Thesis students to pursue assistantships. A student's thesis advisor, at their discretion, may offer an assistantship upon demonstration of exceptional promise in research and academics.

Students in the Professional MS program are not eligible for TA or RA appointments, but are eligible for hourly employment as graders, administrative assistants, and research assistants. These positions do not provide coverage of tuition, fees, or health benefits, but do provide hourly pay, usually at a rate of $18.50 per hour. Requests for hourly support can be submitted via the Hourly Employment Interest Form. The department will solicit students interest in hourly employment prior to each fall and spring semester via the graduate program student listserv.

3.4.3 Sources of Funding

When making sense of different assistantships, appointments, and fellowships, it can be helpful for students to be aware of the different sources of funding that they may come across:

- **Departmental funding:** This funding comes directly from the department in the form of TA or RA appointments and is ultimately allocated by the graduate committee. Individual faculty advisors may be consulted prior to departmental funding decisions, but this funding does not come from sponsored projects or grants. New PhD students are often given departmental support in the form of TA positions, and the Application for Departmental Support can be used by faculty advisors to request support for

Funding Type	Program		
	PhD	*MS Thesis*	*MS Professional*
Teaching Assistantship	✔	✱	✘
Research Assistantship	✔	✱	✘
Chair's Graduate Assistantship	✔	✱	✘
Entrepreneurial Scholarship	✘	✔	✔
Diversity Scholarship	✘	✔	✔
University Graduate Fellowship	✔	✘	✘
Chair's Graduate Fellowship	✔	✘	✘
Tom and Brenda Geers Award	✔	✘	✘
Singh Award	✔	✔	✔
Vogel Family Fellowship	✔	✘	✘
Summer Fellowship	✔	✱	✘

Table 1: ✔ = eligible for this funding type; ✘ = not eligible for this funding type; ✱ = eligible for this funding type, but opportunities are limited/rare.

current students.

- **Sponsored project and grant funding:** This funding comes from externally funded sponsored projects and grants connected, for example, to the National Science Foundation (NSF), the National Institutes of Health (NIH), and the Department of Defense (DoD). Such funding is nearly always used to support RA appointments, with final funding decisions made by individual faculty advisors. Although "gift" funding is contractually different than funding from sponsored projects and grants, it is also typically disbursed by individual faculty advisors in the form of RA positions.
- **Startup funding:** In some cases, students may hear about "startup" funding, in the form of either TA or RA appointments, that faculty may have access to. These are positions promised to faculty by the department but, in contrast to "departmental funding", individual faculty advisors are responsible for deciding when and how to use these positions.
- **Fellowship funding:** This funding is provided by external sources such as the NSF, NIH, or DoD in the form of graduate fellowships (Section 3.8 provides more detail on different types of fellowships). In some cases this funding may be connected to a particular faculty research advisor, but generally students receiving this funding are not contractually obligated to a particular sponsored project, grant, or advisor.

3.4.4 Funding Eligibility Quick Guide

To aid students in finding funding opportunities within the department, we have prepared a funding eligibility quick guide, shown at the top of this page as Table 1. Detailed descriptions of each opportunity are provided in the following sections.

3.5 Assistantships

Assistantships are the primary mechanism for financially supporting PhD students. Recipients are awarded coverage of tuition, 90% of university health plan costs, dental insurance, and a living stipend in the form of a monthly salary. Students on an assistantship are required to work, either in a teaching or research capacity, for up to 20 hours per week during the fall and spring terms. During the summer term, students are eligible to receive assistantships with a 40 hours per week work commitment and an increased living stipend, although most students remain on a 20 hour per week appointment throughout the year. Details of assistantships can vary depending on your faculty advisor; we recommend that all current and prospective students communicate regularly with their faculty advisor about expectations for assistantship funding.

All PhD students are eligible for assistantships. While eligible, MS Thesis students receive assistantship funding on a very limited basis. MS Professional students are not eligible to receive assistantships from any department.

Further information on appointments is available in the CU Graduate Student Appointment Manual.

3.5.1 Teaching Assistantships

Teaching assistants (TAs) play a vital role in supporting the educational mission of the department and the College of Engineering and Applied Sciences. Under the mentorship of faculty, students have the opportunity to develop their pedagogical skills and further enhance their knowledge in the engineering field. Extensive information and resources for TAs are available in Appendix G.

In most cases, TAs will be assigned to support an undergraduate mechanical engineering course. However, in limited cases, some students may support graduate-level and/or courses outside the department.

The number of TA hours allocated to each course is dictated primarily by the number of students enrolled in the course. TA assignments are made by the graduate chair and graduate advisors with input from instructors, PhD advisors, and students. Prior to assignment of TAs, a survey is sent to students requesting course preferences and, in nearly all cases, TAs are assigned to one of their top-three preferred courses.

3.5.2 Research Assistantships

In most cases, research assistants (RAs) are funded directly by faculty through sponsored project or grant funding. As such, specific duties will vary based on the nature of the research and the faculty member. In conjunction with the PhD curriculum, research assistantships provide broad exposure to the research process from grant proposal to publication.

In addition to faculty funded research assistantships, PhD students may be offered a special assistantship in recognition of their outstanding potential. All PhD applicants are automatically considered for special assistantships with their application for admission. Current PhD students are not eligible to be considered for special assistantships.

- **Chair's Graduate Assistantship:** The Chair's Graduate Assistantship is funded by the Department of Mechanical Engineering. It is intended to support outstanding students during their first year of graduate studies, with an emphasis on selection of candidates that demonstrate exceptional leadership and contribution to diversity.

3.5.3 Compensation Rates

Monthly stipend compensation rates for student assistantships, based on PhD student status, are the following:

- *Pre-comprehensive exam:* $2,755 per month
- *Post-comprehensive exam:* $2,884 per month

Additional detail on these PhD student statuses is available in Chapter 4. MS Thesis students with RA/TA appointments are paid at the pre-comprehensive exam compensation rate.

3.5.4 English Language Proficiency Requirement

International students assigned as RAs or TAs are required by the College of Engineering and Applied Sciences to take an English language screening test, administered by the International English Center and described in more detail here. If a student fails this test, they may either be recommended or required to take the course ELSG 1130: Pronunciation for International Graduate students, described here. This course is designed for international graduate students who want to polish and refine their spoken English skills. For students required or recommended to take this course, the cost of the course ($880 total) will be fully covered for them.

3.6 Scholarships and Fellowships

3.6.1 Diversity Scholarship

Diversity and inclusivity are values embodied in the strategic visions of both the College of Engineering and Applied Sciences and the Department of Mechanical Engineering. We are committed to fostering a diverse and equitable environment for our students in all respects, inclusive of financial support. The Diversity Scholarship offers incoming and current students the opportunity to apply for funding worth $1,000 – $4,000 per semester.

The application for the Diversity Scholarship will be available each semester. The graduate program will market, the application deadlines and specific requirements for the scholarship via the graduate student listserv and the department website. While students may apply for the scholarship during any semester the application is open, preference will be given to students who have not previously been awarded a diversity scholarship.

3.6.2 Entrepreneurial Scholarship

As one of the top public Mechanical Engineering departments in the United States, conveniently located in one of the most well-respected technology hubs in the country, entrepreneurial opportunities are abound in Boulder. Students with a demonstrated ability and/or interest in entrepreneurship may apply for the scholarship, which may be worth between $1,000 – $4,000 per semester.

The application for the Entrepreneurial Scholarship will be available each semester. The graduate program will market, the application deadlines and specific requirements for the scholarship via the graduate student listserv and the department website. While students may apply for the scholarship during any semester the application is open, preference will be given to students who have not previously been awarded an Entrepreneurial Scholarship.

3.6.3 Singh Graduate Fellowship

Shrawan Kumar Singh and Sudha Singh have generously established a fellowship intended to provide financial support to mechanical engineering students pursuing graduate studies within the department. Students that have research interest in bioengineering and/or biomechanical studies are given preference for this fellowship. Award amounts and lengths may vary. Students will automatically be considered for this fellowship by the graduate committee and departmental leadership.

3.6.4 Tom and Brenda Geers Graduate Fellowship

Thomas L. and Brenda Geers have generously established a fellowship intended to provide one student pursuing a PhD in mechanical engineering with fellowship support. Students who are pursuing work in solid and/or fluid mechanics that have attained post-prelim status are eligible for the fellowship. Possible fellows are considered automatically by the graduate committee and may be awarded a fellowship for up to three years. Award amounts may vary and only one student at a time can be designated a Geers Fellow.

3.6.5 Vogel Family Fellowship

Herbert and Karen Vogel have generously established a fellowship intended to provide one mechanical engineering student pursuing research in the area of thermodynamics, heat transfer or fluid flow with fellowship support. Possible fellows are considered automatically by the graduate committee and may be awarded a fellowship for up to three years.

3.6.6 University Graduate Fellowships

University Graduate Fellowships are awards supported by the University of Colorado and the Graduate School. PhD applicants are automatically considered with their application for admission. University Graduate Fellowships are awarded to the top applicants for each incoming class of PhD students. Fellowship amounts can vary, with a maximum award of $5000 per year. These awards are provided in addition to the tuition, health insurance and living stipend provided by a student's assistantship.

3.6.7 Chair's Graduate Fellowships

Chair's Graduate Fellowships are awards supported by the Department of Mechanical Engineering. PhD applicants are automatically considered for this fellowship with their application for admission. Chair's Graduate Fellowships are awarded to applicants that show exceptional potential during the admissions process. These awards are provided in addition to the tuition, health insurance and living stipend provided by an assistantship.

3.6.8 Summer Fellowships

PhD students who have not received an assistantship offer for the summer term who wish to continue working in their lab may be considered for a summer fellowship. These fellowship awards do not cover any summer

tuition costs or health/dental insurance. The fellowship is intended to supplement summer living expenses while the student continues to support faculty research. The amount of the fellowship is equivalent to three months of pay at the rate appropriate to the status of the student (provided in Section 3.5.3).

Applications for summer fellowships are submitted using the Application for Department Support process, described in detail in Section 3.9.

Please note that students on a summer fellowship are not considered university employees. As such, they MUST be set up as a POI (Person of Interest) through the department's HR representative prior to the start of the summer semester. Failure to take this step will result in losing access to labs and other areas of campus that require a POI or employment status, as well as inactivation of procurement and travel cards.

Additionally, students should understand that fellowships are paid in one lump sum, rather than spread throughout the summer semester. Students should plan accordingly to ensure their funds last through the summer. Pay stubs are not generated for summer fellowship students due to the nature of this type of compensation. If you have need to demonstrate your summer income for any purpose (i.e., verification of income for housing, etc.), please reach out to your graduate advisor, who will be happy to write a letter to explain the nature of your summer funding.

3.7 Hourly Employment

The department regularly employs graduate students in hourly positions. Students in hourly positions may engage in either course, research, or administrative support. Hourly pay for a research project requires the commitment and support of a faculty advisor.

Hourly positions typically span 5-20 hours per week during the academic year and up to 40 hours per week during the summer. Students in hourly positions are not permitted to work more than 20 hours per week during the academic year or 40 hours per week during the summer. Compensation rates vary by position.

Hourly employment is available for any graduate student who is not funded through a TA or RA position or similar external funding, though requirements can vary based on position.

The graduate program typically requests students interested in hourly employment complete the Hourly Employment Interest Form twice per year; once for consideration for fall positions and once for spring positions. The graduate program will reach out to students, via the graduate student listserv, when applications are open. Selection for these positions can be competitive due to semester-to-semester variance in the number of positions available. Please note that while a faculty member may provide an informal offer of hourly employment, all hourly employees must be reviewed (for eligibility purposes) and approved by the graduate program before an official offer of employment can be made.

Occasionally, hourly employment opportunities arise on an ad-hoc basis. Any such opportunities will be marketed to students through the graduate student listserv.

Note that, unlike assistantships, hourly employment does not cover tuition, fees, or health insurance.

3.8 External Funding and Fellowships

A short list of funding opportunities that mechanical engineering students have applied for in the past are listed below. This list does not encompass all external funding opportunities. Faculty advisors may also have more information about external funding opportunities for specific fields of study.

- National Science Foundation Graduate Research Fellowship: More information here
- National Defense Science and Engineering Graduate Fellowship: More information here
- NASA Earth Science Fellowship: More information here
- Blue Waters Graduate Fellowship: More information here
- Draper Fellow Program: More information here
- Interdisciplinary Quantitative Biology Fellowship: More information here

- National Institutes of Health F31 Fellowship: More information here
- National Institutes of Health Training Grants through other CU departments

Additionally, the graduate school provides an extensive list of funding opportunities found here. A list of recent mechanical engineering graduate students with external fellowships and awards is available here.

3.9 Application for Departmental Support

The Application for Departmental Support is for faculty advisors of mechanical engineering PhD students to request departmental support (in the form of either department-supported TA or RA positions). Selection of students for financial support is based on need, prior departmental support received by the student, merit, and the availability of funds. Preference will be given to currently enrolled PhD students, although applications may be submitted and will be reviewed for MS Thesis students. Typically, 5-10 such awards are offered per semester, including the summer.

Note that this application process is specifically intended for non-1st year PhD students who may have a gap in funding or another reason for requiring departmental support. If a student did not receive a department-supported TA or RA position during their first year (e.g., the student was supported on an NSF fellowship or sponsored project RA), that should be noted in the application and will be taken into consideration.

Support provided through this application process is only for one semester at a time. Separate applications must be submitted to request support in future semesters. There are three review cycles for departmental support per year, corresponding to support during fall and spring semesters, and the summer.

Questions about this process may be directed to the graduate advisors at megrad@colorado.edu. PhD students who would like to receive department support but who do not have a faculty advisor should contact the graduate advisors.

3.10 Travel Awards

There are many travel award opportunities available to graduate students. Deadlines for these grants are communicated via the graduate student listserv whenever possible and can be checked at the links below.

- **Department Travel Grant:** https://www.colorado.edu/mechanical/graduate/funding-and-fellowships
  The Department of Mechanical Engineering accepts applications for travel grants for up to $250 for in-state conferences and up to $750 dollars for out-of-state conferences. Applications are accepted throughout the academic year and are reviewed by the Graduate Committee. Funds are limited, so applying early is encouraged.
- **UGGS Travel Grant:** https://www.colorado.edu/uggs/grants
  Fall Grants cover travel and events taking place between September 1, 2021 and March 1, 2022. Spring Grants cover travel and events taking place between March 1, 2022 and September 1, 2022. The United Government of Graduate Students (UGGS) awards funding (up to 300 dollars) to individual graduate students each academic semester to support travel to academic conferences, meetings, or other events related to the student's studies.
- **Graduate School Travel Grant:** https://www.colorado.edu/graduateschool/awards#Grad_Travel_Grant
  This grant has three application cycles per year for domestic (including Mexico and Canada) and international (excluding Mexico and Canada) travel. The dates for the application cycle can be found in the link above. All applications open at 12:01AM MST on the open date and close at 11:59PM MST on the date listed. If you received travel grant funding from the Graduate School during the last application cycle (May for current fall applicants, November for current spring applicants) you may not apply during this cycle. Masters students can receive travel funding once, and PhD students can receive funding twice during their studies at CU. The Graduate School provides a travel grant of $300 for domestic conferences and $500 for international conferences.
- **Dean's Travel Grant:** https://www.colorado.edu/engineering/content/deans-matching-travel-grant

Graduate students must first apply for, and be denied, funding through the Graduate School before submitting this application. Applications must be submitted a minimum of 2 weeks prior to travel departure to allow for processing time.

3.11 Other Funding Opportunities

3.11.1 Distinguished Dissertation Award

Each year, the department awards the PhD student with the most outstanding dissertation the Distinguished Dissertation Award. The award recognizes the recipients excellence in research and scholarship and provides a $1,000 award. Students selected for this award are also entered into the College of Engineering Distinguished Dissertation Award competition.

3.11.2 Thesis/Dissertation Printing

The department covers the costs of printing and binding two copies of any mechanical engineering graduate student's final thesis or dissertation, (up to $125). One copy is intended to remain with the student for their personal use and the second copy is to be provided to the department. If you are interested in this option, please reach out to the graduate advisors at megrad@colorado.edu for additional details.

3.11.3 Compensation for Service Leadership

Graduate students play a pivotal role in recruitment and administrative service leadership efforts across the department. In recognition of these contributions and time expended, these student leaders are offered compensation in the form of a stipend. Below are a list of leadership roles that recur on a yearly basis and the compensation for said role.

- **Graduate committee student representative:** $500 per semester of service
- **GEARRS co-presidents:** $750 per semester of service
- **GEARRS committee leads:** $300 per year of service
- **Oral preliminary exam subject area leads:** $250 per year of service

Ad hoc service leadership positions may be available on an irregular basis depending on departmental needs; in those cases, compensation will be provided for substantial contributions and time commitment as well; those rates will be provided to the student prior to accepting the leadership role.

3.11.4 Student of the Month

The graduate program will name one Student of the Month for each month of the academic year (September - May). Nominations may be submitted by any student, staff or faculty member in the mechanical engineering department via the Student of the Month form. Recipients will be acknowledged on the department website and will receive a $200 award. Students are eligible to be named student of the month on multiple occasions, though preference will be given for students who have not previously received the recognition. If you have questions about the Student of the Month, please reach out to the graduate advisors at megrad@colorado.edu.

3.11.5 Bus Pass Reimbursement

Students on appointment are eligible to be reimbursed for the purchase of a student bus pass. Please contact megrad@colorado.edu for more information on how to request this reimbursement.

3.12 Taxes

Graduate students are responsible for taxes according to the rules and regulations of the Internal Revenue Service (IRS). Graduate advisors and financial staff in mechanical engineering are not trained or able to provide advice on taxes, but substantial info is available through the Bursar's Office. Please note that there may be special requirements for international students; more information can be obtained here.

3.13 Pre-Enrollment Pay Policy

Faculty will occasionally invite incoming PhD or MS Thesis students to begin working in their lab prior to the student's first term of enrollment at CU. In these cases, students are eligible to be paid as an hourly employee,

but are not eligible for an RA appointment. The hourly rate available may change from year-to-year, but currently pays $18/hr.

Students are admitted to the department for the term in which they apply. Changes to this start term, after an offer of admission has been delivered, will not be permitted for the sole purpose of pre-enrollment employment.

3.14 Important Note on Full-Time Status and Financial Aid

The Graduate School's definition of full-time student status can vary from the requirements for full-time student status in regards to financial aid. If you have any funding from outside the department or your research group, it is important to ensure you communicate with the financial aid office and funding sponsors about possible enrollment requirements you may be subject to. This is also true if you are deferring any student loan payments from previous degrees. In both cases, enrollment requirements may be higher than the Graduate School requires.

4 PhD Degree Program

4.1 Overview

The PhD program in mechanical engineering is available to students who are entering graduate studies for the first time (i.e., with only a BS or BA degree), as well as to those who already have a master's (MS) degree. While an MS degree is not required to enroll, PhD students without a prior MS degree are typically able to earn one on the way to their PhD degrees. Many incoming PhD students will have prior degrees in some type of engineering, although students from other fields, such as physics, mathematics, biology, and chemistry, are also routinely admitted and can acquire any missing background material during the course of their PhD studies at CU. Students graduating with a PhD from mechanical engineering are expected to have extensive fundamental and foundational knowledge in their field of study, in addition to being research experts.

4.2 Mission Statement

The primary objective of the PhD degree program is to educate students to the highest levels of their chosen field, in order to make lasting and significant impacts to fundamental knowledge, technology, and society through their research. PhD students are expected to become domain experts and to complete research that can withstand the rigorous test of external peer review. Graduates from the PhD program go on to careers in industry, academia, and the public sector, and are expected to become leaders in their respective fields. Each PhD graduate is a lifelong representative of CU and the Department of Mechanical Engineering and, as such, is expected to act professionally, ethically, and with integrity during their time at CU and beyond.

4.3 Timeline

A PhD student entering without prior graduate coursework will typically take 5 years to complete the PhD degree. However, it is not uncommon for students to finish both earlier and later than this five-year average. A student entering the PhD program with prior graduate coursework from another university may be eligible to transfer up to 21 credit hours to CU and can typically finish in 3-4 years. Regardless of the time taken to complete the PhD, the primary emphasis is on remaining at CU long enough to complete high quality research that satisfies the requirements of the PhD dissertation and defense. If a student is nearing the completion of their 6th year in the PhD program, they are required to file a time-limit extension via this online form. Please contact the graduate advisors at megrad@colorado.edu for more information on requesting a time limit extension.

4.4 Requirements

Table 2 provides a description of each major requirement leading to completion of the PhD degree in mechanical engineering. A checklist of PhD graduation requirements is also available from the Graduate School here.

Requirement	Notes	Typical completion
Pre-preliminary exam student status		
Mathematical proficiency	B- or higher in MCEN 5020: Methods of Eng. Analysis	End of 1st semester
Research group selection	Research expectations form	End of 1st semester
Research development	B- or higher in MCEN 5208: Intro. to Research	End of 1st semester
Oral preliminary exam	Two 30 min subject area exams	End of year 1
Post-preliminary exam student status		
Research preliminary exam	1 hour research presentation	End of year 2
Course hours	30 hours, with 9 hours of MCEN classes	End of year 2
Comprehensive exam	Oral presentation and report	End of year 4
Post-comprehensive exam student status		
Dissertation hours	30 hours	End of year 5
Written dissertation	Completed 2 weeks before defense	End of year 5
Dissertation defense	Oral presentation	End of year 5

Table 2: Requirements leading to the PhD degree, including typical completion dates and updates to student status. Dates listed are typical for completion.

4.4.1 Course Requirement

PhD students must complete a minimum of 30 graduate-level credits at the 5000 level or higher. Of these 30 credits, at least 9 must be Department of Mechanical Engineering courses (denoted by the "MCEN" course prefix). All PhD students are required to take the following courses:

- MCEN 5020: Methods of Engineering Analysis I (3 credits); and
- MCEN 5208: Introduction to Research (3 credits)

Some research advisors will require that their students complete more than 30 course credits. The graduate program recommends that, in addition to their graduate advisor, students consult their research advisor regarding any coursework recommendations or requirements. Additional detail on ME graduate courses is provided in Appendix D.

In order to receive credit towards the PhD, students must receive a grade of at least B- in each course taken. Courses in which a grade below B- is achieved cannot be counted towards the PhD course requirement. Courses taken on a P/F basis cannot count towards the PhD course requirement.

Students must have a cumulative 3.0 GPA in order to be eligible for graduation. However, a 3.25 GPA is required for students to be eligible for Teaching or Research Assistantships.

4.4.2 Transfer Credit

Although students do not need an MS degree to be admitted to the PhD program, students who already have an MS degree, or have completed eligible graduate level coursework, may transfer up to 21 hours of credits towards the PhD course requirements. More information is available on the second page of the Request for Transfer of Credit Form from the CU Graduate School. To transfer credits, students must fill out and submit this form to their graduate advisor at megrad@colorado.edu with an official transcript(s) included.

Note that requests for transfer credit can only be made after completing 6 credits of graduate level coursework at CU. These requests should be submitted as soon after completion of this 6 credit requirement as possible. Typically, this means that transfers of credit are processed during the second semester of PhD study at CU. Additional information on transfer of credits is available in Section 6.7 of Chapter 6.

4.4.3 Mathematical Proficiency Requirement

All PhD students are required to take MCEN 5020: Methods of Engineering Analysis and to pass with a grade of B- or higher. Students receiving a grade below B- in MCEN 5020 must retake the course.

PhD students will not be able to advance to post-prelim status until the mathematical proficiency requirement has been completed. Failure to complete this requirement by the end of the second year of the PhD may result in removal from the PhD program.

4.4.4 Research Expectations Form

The Research Expectations Form is intended not only to formalize the agreed-upon relationship between research advisor and student, but also to assist with strategically designing the curriculum and research goals of your PhD program. The form should be completed as soon as a research advisor is found, and no later than the end of your first semester in the PhD program. This form is also a required element in MCEN 5208: Introduction to Research, which is used to satisfy the Research Development requirement (see Table 2).

Students will need to work with their research advisors to identify the oral preliminary exam topics they plan to take, any core foundational coursework they need to complete, and expectations for funding during their first year, inclusive of the summer term.

PhD students are eligible to work with research advisors at CU outside the Department of Mechanical Engineering (e.g., professors in aerospace engineering sciences or civil engineering); in such cases, the advisor consent form must still be completed in its entirety.

In the event that a PhD student has two or more faculty members serving as co-research advisors, one co-advisor should be chosen to serve as the primary administrative advisor. This faculty member will serve as the named professor for dissertation hours enrollment and, upon completion of the dissertation, will need to sign off on a final grade (in consultation with the co-advisor) for those credits.

4.4.5 Research Development Requirement

The Department of Mechanical Engineering is committed to educating well-rounded PhD students who are prepared to excel in their chosen professional careers after graduation, whether in industry, academia, or the public sector. Throughout the academic year, the department offers a wide variety of seminars, colloquia and workshops that assist in the professional development of students beyond the classroom and lab.

Our commitment to the research and professional development of our PhD students is codified by the Research Development requirement, which is fulfilled by obtaining a passing grade (i.e., B- or above) in MCEN 5208: Introduction to Research. This course, offered every fall semester, provides a strong foundation in a variety of topics related to research that will prove valuable both as a student and professional. Covered topics include ethics in research, literature review, and grant writing, among others. The Research Development requirement must be completed before proceeding to post-preliminary exam status.

4.4.6 Oral Preliminary Exam

All PhD students must successfully pass the oral preliminary exam, which is intended to assess the potential to successfully complete a PhD in mechanical engineering. It is designed to evaluate analytical skills, appraise knowledge of mechanical engineering fundamentals, and to gauge potential for creative independent research. The exam requires students to consolidate their grasp of the fundamentals of mechanical engineering and to demonstrate an aptitude for communicating knowledge during an oral presentation. The content of the examination reflects consensus across the department faculty. The examination is administered by the Graduate Committee, acting on behalf of the entire faculty.

All PhD students are required to take two from a list of multile topic exams. Concept inventories are provided for each topic in Appendix E and peer-led oral exam practice efforts are organized to facilitate growth with oral defense. The list of topics and their corresponding preparatory courses are listed below:

- **BioM**^{3} (offered for students enrolled prior to Fall 2022): MCEN 5117 Anatomy & Physiology for Engineers
- **Controls**: MCEN 5228 Linear Systems
- **Fluid Dynamics**: MCEN 5021 Introduction to Fluid Dynamics
- **Heat Transfer**: MCEN 5042 Heat Transfer

- **Materials**: MCEN 5024 Materials Chemistry and Structures
- **Mechanics**: MCEN 5023 Solid Mechanics
- **Thermodynamics**: MCEN 5022 Classical Thermodynamics

Although the preparatory courses are strongly recommended prior to taking the oral preliminary exam, they are not required.

The exam is oral and delivered by a committee of at least two faculty. The committee cannot include a student's faculty advisor, and advisors are not consulted when making final decisions on exams.

Oral preliminary exams are administered the first week of the fall semester, and will typically be taken by PhD students at the beginning of their 2nd year. In consultation with their research advisor, students entering the PhD program with the appropriate foundational knowledge may choose to take the oral preliminary exams in their first fall semester.

Based on student performance, the preliminary exam committee will provide an evaluation of pass, conditional pass, or fail. If the result is a conditional pass, the committee may require the student to retake a portion of the exam or to complete another condition that displays fundamental proficiency. If a student fails a preliminary exam, they will either be asked to retake the exam in full the next fall, or may be asked to leave the PhD program. Students who fail a preliminary exam twice will be asked to leave the PhD program.

4.4.7 Research Preliminary Exam

The Research Preliminary Exam is an oral presentation of research to a committee of three that must include a PhD student's research advisor and at least one other faculty member from mechanical engineering. Students should view this as an early thesis proposal.

At least one week prior to the exam, students must send a research proposal to all committee members. The department does not schedule these exams; students must organize the exam and coordinate schedules with the committee. Students should bring the research prelim form with them to the exam; this form is available here.

Typically, the research preliminary exam consists of a roughly 30 minute oral presentation by the student on a research topic, followed by roughly 30 minutes of questioning by the exam committee. In nearly all cases, the total exam time should be, at most, 1 hour.

The research preliminary exam should be completed within 1 year of passing the oral preliminary exam, but no later than fall semester of the 3rd year. Students who fail the research preliminary exam must retake the exam and pass within 1 year of the first exam; failure to pass this exam may result in removal from the PhD program. Students who conditionally pass the research preliminary exam will typically have less than a year to complete their condition; again, failure to satisfy the condition(s) may result in removal from the PhD program.

Additional details on the research preliminary exam, including the rubric by which students are evaluated, is provided in Appendix F.

4.4.8 Comprehensive Examination

Students must complete a comprehensive exam between 6 and 12 months prior to defending their PhD dissertations. At the time of the comprehensive exam, the dissertation committee will be formed and given preliminary approval by the Department and Graduate School.

A mechanical engineering PhD degree requires depth of knowledge in the dissertation/research area, as well as breadth of knowledge across the mechanical engineering curriculum. Consequently, the comprehensive exam is designed to test student knowledge of their proposed research area, and any general knowledge in the field. It is also intended to evaluate whether a student's proposed research project is original and creative work, whether it will make a significant impact in the field, and whether it will qualify for publication in quality peer-reviewed journals. The exam is also an opportunity to demonstrate an ability to present scientific concepts

orally. In short, the comprehensive exam serves as the gateway to the next phase of the doctoral program: completion of a dissertation.

The comprehensive exam consists of the following core requirements:

- Submit a Doctoral Examination Report and a Candidacy Application for Advanced Degree to the mechanical engineering graduate advisors at least three weeks prior to the comprehensive exam.
- By email, send the comprehensive exam proposal to (*i*) the examining committee and (*ii*) the graduate advisors at least two weeks prior to the examination. The proposal should describe the work that has been completed to date and proposed work that will be completed for the dissertation.
- Included in the proposal should be a comprehensive literature review of the field of concentration, the subject of the dissertation, as well as a detailed timeline of work to be completed prior to the dissertation defense. In most cases, the proposal should be written in the style and format of the final dissertation document.
- Students must prepare a professional oral presentation that covers what is written in the proposal. This presentation should be 45-50 minutes in length and must be delivered at the comprehensive examination to the examination committee. The oral presentation portion of the examination is open to all students and faculty, and questions are entertained at the end of the presentation.
- The final part of the examination is restricted to only the student and the examination committee. During this portion, questions are entertained that cover the field of concentration and related fields.
- Successful candidates must receive affirmative votes from a majority of the members of their examination committee.

Students who fail the examination may attempt it once more after a period of time determined by the examination committee. Additional administrative requirements of the comprehensive examination are as follows:

- All program coursework must be completed before taking the comprehensive exam.
- Students must be registered as regular degree-seeking students when they take the comprehensive exam (thus requiring a minimum enrollment of 1 credit hour).
- Each comprehensive exam committee is comprised of five members. The department requires that three of the members be mechanical engineering faculty and one must be a regular CU faculty member from another department.
- Each committee member must have a regular or special faculty appointment on file with the Graduate School prior to submission of the Doctoral Exam Report. Please contact the graduate advisors at megrad@colorado.edu as soon as you form your committee, and no later than 6 weeks prior to your comprehensive examination, to verify that the necessary appointments are in place. It takes 2-4 weeks to process a faculty appointment. Students should submit a recent CV for any committee member who does not have a faculty appointment to the graduate advisors as soon as possible.

4.4.9 Dissertation Hour Requirement

In addition to coursework, PhD students are required to complete 30 PhD dissertation hours. Students are not able to register for dissertation credits on their own and should submit a request for dissertation hours through the Thesis/Dissertation Credit Hours Request Form.

The following Graduate School rules apply to enrollment in dissertation hours and should be considered when determining how many dissertation hours to register for each semester:

- PhD students must be registered as full time, regular degree-seeking students at CU for a minimum of 5 dissertation hours during the semester in which they defend the dissertation.
- A student may not register for more than 10 dissertation credit hours in any one semester, including summer.
- A PhD student is required to register continuously as a full-time student for a minimum of five disser-

tation hours in the Fall and Spring semesters of each year, beginning with the semester following the passing of the comprehensive examination and extending through the semester in which the dissertation is successfully defended.
- Prior to passing the comprehensive exam, PhD students are considered by the Graduate School to be full-time if they are registered for at least 1 dissertation credit per semester.

There is little advantage to a student registering for more than 30 dissertation hours during the course of their PhD, and so students should attempt to complete this requirement in the semester in which they defend. Please contact the graduate advisors at megrad@colorado.edu for assistance with planning dissertation hour enrollment.

4.4.10 Written Dissertation

The written dissertation must comply with Graduate School rules and procedures in terms of format and submission. Full details on formatting requirements are available here, and deadlines and resources to assist in finalizing your dissertation are available here. Both Word and LaTeX templates for written dissertations are available here.

The dissertation title appears on official university transcripts and must be submitted to the Graduate School in addition to the physical signature page from the dissertation. Students are also required to submit the full written dissertation electronically at the ProQuest website. The timeline for these requirements is as follows:

- Final dissertation title submission is due about two months into the final semester.
- The oral dissertation defense must be passed shortly after this date.
- One week after the defense deadline, students must submit:
  - The written dissertation, electronically; and
  - The physical signature page, signed by all committee members, to the Graduate School.

  Both of these items can be completed using the form provided here.

Please see Chapter 3 for information on department support for dissertation printing costs.

4.4.11 Dissertation Defense

Before completion of the PhD degree, students must have their dissertation accepted for defense by the review committee. The dissertation defense may occur before or after the final electronic submission of the written dissertation to the Graduate School, but must take place prior to the end of the final semester of enrollment.

Students must then pass a dissertation defense, which is a final examination on the dissertation and related topics. In the defense, students are expected to explain their research clearly and concisely, and to discuss how it relates to other research in the field. This is an opportunity for recognition of completed doctoral work. It is also an opportunity for discussion and formal evaluation of the dissertation.

All required forms should be submitted on time according to the following deadlines:

- **To the Department:** The Doctoral Examination Report should be submitted to the graduate advisors at megrad@colorado.edu at least 3 weeks prior to the defense.
- **To the Committee:** The written dissertation should be sent as a single pdf file by email to all members of the defense committee, as well as to the graduate advisors at megrad@colorado.edu, at least 2 weeks before the defense. This deadline is intended to allow the defense committee sufficient time to review the dissertation and to formulate questions and feedback. Prior to the defense, students should contact all members of the committee to assess their areas of interest and concerns. This will help students anticipate any questions that will be asked.

Students must be registered as full time, regular degree-seeking students at CU for a minimum of 5 dissertation hours during the semester in which they pass the examination. The examination is conducted by a committee appointed by the chair of the major department and approved by the Dean of the Graduate School, and consists

of at least five people with the following requirements:

- One committee member must be outside the student's major department;
- Three of the members must be ME faculty.

The chair and outside member of the committee must have regular or tenured Graduate Faculty appointments. The other committee members must have either regular or special Graduate Faculty appointments. More than one dissenting vote disqualifies the candidate in the final examination. The committee chair and a majority of the committee must be present on the Boulder campus for the examination.

Students should coordinate scheduling the examination with the committee, and should schedule the examination for two hours. The examination is wholly oral and open to the public for the first portion of the examination.

Students must prepare and present a professional oral presentation that summarizes the dissertation. This presentation should be 45-50 minutes in length and delivered to the examination committee. The oral presentation portion of the examination is open to all students and faculty. Questions are entertained at the end of the presentation.

The final part of the examination is closed to only the student and the examination committee. During this portion, questions are entertained that cover the field of concentration and related fields. More than one dissenting vote among the committee constitutes an unsatisfactory exam. A student who fails the exam may attempt it once more after a period of time determined by the committee.

4.5 PhD Student Status

As the requirements towards the PhD degree are completed, PhD students will advance from pre-preliminary exam, to post-preliminary exam, to post-comprehensive exam, status. Milestones required to achieve each status are the following:

- **Pre-preliminary exam status (Pre-prelim)**: Students enter the PhD program with pre-prelim status and will typically remain at this status through their first three semesters at CU.
- **Post-preliminary exam status (Post-prelim)**: Completion of mathematical proficiency requirement, research development requirement, and the oral preliminary exam. PhD students typically advance to this status during their 3rd semester (i.e., the middle of year 2) at CU. This status is also sometimes referred to as "Pre-Comprehensive Exam" status.
- **Post-comprehensive exam status (Post-comps)**: Completion of the comprehensive exam and the course requirement, typically by the end of year 4 at CU.

4.6 Application for Graduation

In order to graduate with the PhD degree, students must complete all course and dissertation hour requirements, as well as write and defend their dissertation. Additional details on each of these requirements are provided above.

To graduate with the PhD degree, students must apply online through their myCU portal. On the "Student" tab, select the "Apply for Graduation" link under "Academic Resources".

The application for graduation is due a few weeks after the start of the desired graduation semester. Full details on requirements and deadlines can be accessed on the Graduate School PhD graduation webpage. If you did not submit the Candidacy Application for Advanced Degree when completing the comprehensive examination, it must be submitted to the graduate advisors at megrad@colorado.edu prior to applying for graduation online.

PhD students must be registered as a full time, regular degree-seeking student, for a minimum of 5 dissertation hours during the semester in which they pass the final exam. If a student is unable to meet the Graduate School's posted defense deadline for that semester, they should consult with their graduate advisor about graduation options.

Detailed graduation information will be communicated to all students through the graduate student listserv at the beginning of each semester.

The graduate program conducts an annual survey of PhD students that evaluates the overall PhD student experience within the mechanical engineering department over the previous academic year. The survey will be conducted anonymously and a report of results will be shared with faculty, staff and students within the department.

4.7 Master's Degree as a PhD Candidate

Although a Master's degree is not required for a PhD, students can earn one while working toward the PhD. This is accomplished by applying for an MS degree when 30 graduate course hours have been completed. All requirements described in Chapter 5 must be completed in order to receive the MS degree; the procedure to apply for graduation with the MS degree is also provided in this chapter. PhD students must notify their graduate advisor within the first two weeks of the semester in which they intend to graduate with the MS degree.

5 Master's Degree Programs

5.1 Overview

Master's degree students in mechanical engineering take graduate courses and participate in research and/or project based learning as part of four different program choices, each leading to a master's of science (MS) degree in mechanical engineering.

- **MS Professional Program:** This coursework-focused degree program emphasizes both project-based and curriculum-driven learning. It is targeted at working engineers and undergraduates considering, or already pursuing, a career in industry, but can also be completed with the ultimate goal of matriculating in a PhD program.
- **MS Thesis Program:** This program is intended for MS students interested in a short-term research experience, leading to the preparation and defense of a research-based thesis. The program emphasizes education through high quality research for students interested in careers in industry, the public sector, and academia.
- **Bachelor's Accelerated Master's (BAM) Program:** Current undergraduate students in mechanical engineering may pursue either an MS Professional or MS Thesis degree through this program. The BAM program in mechanical engineering is also available to undergraduate students from environmental engineering.
- **Dual Degree in Mechanical Engineering and Engineering Management:** This program allows students to earn two master's degrees after completing 45 graduate credits. Dual degree students can pursue either the MS Professional or MS Thesis options for their mechanical engineering degree.

Many incoming MS students will have prior degrees in some type of engineering, although students from other fields, such as physics, mathematics, biology, and chemistry are also routinely admitted and can acquire any missing background material during the course of their MS studies.

5.2 Mission Statement

The graduate program is committed to educating innovative, entrepreneurial, and fundamentally knowledgeable master's students who are prepared to excel—and lead—in their chosen professional careers after graduation, whether in industry, academia, or the public sector. This will be accomplished through high quality hands-on, project-based education in the classroom and in-depth training in the lab, as well as through extensive professional development opportunities offered by the department, college, and university. Through online, distance, and applied courses, the graduate program seeks to cater to current professionals and non-

traditional students seeking to attain a master's degree. Each graduate of the master's program is a lifelong representative of CU and, as such, is expected to act professionally, ethically, and with integrity both during their time at CU and beyond.

5.3 Timeline

Most MS Professional students complete the requirements for the degree in 2 years of full-time study, although it is not uncommon to graduate in 3 semesters or to take more than 2 years, particularly if a student is also working full-time.

MS Thesis and dual degree students typically require at least 2 years to complete their degrees. BAM students may require two or three additional semesters of study beyond completion of their undergraduate degrees to complete their graduate degree requirements.

Full-time study is defined by the Graduate School as enrollment in 5 or more graduate credits per semester. Part-time study is permissible throughout the duration of the program, or for select semesters, as long as the following Graduate School requirements are met:

- Full-time enrollment for at least 2 semesters; or
- Part-time enrollment for at least 4 semesters; or
- Full-time enrollment for 1 semester and part-time enrollment in 2 or more semesters.

Master's students, whether part- or full-time, must complete their degree requirements within 4 years of their first semester of enrollment. If more time is needed, students can request a time-limit extension from the Graduate School by filing a time-limit extension via this online form. Please contact the graduate advisors at megrad@colorado.edu for more information on requesting a time limit extension.

5.4 Requirements

5.4.1 Professional MS Degree Program

Students in the Professional MS degree program can enroll in any combination of coursework that they would like, and a list of mechanical engineering graduate courses is provided in Appendix D.

All MS Professional students must complete the following requirements to be eligible for graduation:

- **Coursework:** 30 graduate-level credit hours must be completed with at least a grade of C in each course. At least 18 credits must be in mechanical engineering (i.e., MCEN courses). Up to 12 credit hours may be taken outside the department, inclusive of any transfer credits applied towards the degree. Students must maintain a cumulative 3.0 GPA to remain in good standing.
- **Professional development:** the three-credit hour course MCEN 5208: Industry Skills must be completed with a grade of at least C. This course is offered every spring semester and consists of a series of seminars, workshops, and projects focused on various topics relevant to careers in industry, including project management, engineering ethics, communication skills, technical writing, resume preparation, budget preparation and management, leadership styles and philosophies, and interview skills.

5.4.2 MS Thesis Degree Program

In order to enroll in the MS Thesis program, students must first secure a thesis advisor. Once an advisor has been found, students may be admitted into the MS Thesis program from the Professional MS, BAM, BS/MS, or even PhD program by following the procedures outlined in Section 2.7.

MS Thesis students should consult with their thesis and graduate advisors for course selection recommendations. Students in the MS Thesis program can enroll in any combination of coursework that they would like, and a list of mechanical engineering graduate courses is provided in Appendix D.

MS Thesis students must complete the following requirements to obtain the MS degree:

- **Coursework:** 30 graduate-level credit hours must be completed with a grade of C or higher in each course. All MS Thesis students must complete the following courses:
  - MCEN 5020: Methods of Engineering Analysis I (3 credits)
  - MCEN 5208: Introduction to Research (3 credits)
  - MCEN 6959: MS Thesis (6 credits)

  At least 18 credits must be mechanical engineering credits, including the 6 required thesis hours. Up to 12 credit hours may be taken outside the department, inclusive of any transfer credits applied towards the degree. Students must maintain a cumulative 3.0 GPA to remain in good standing.
- **Thesis advisor selection:** Upon finding a research advisor, MS Thesis students should complete the MS Thesis Research Expectations Form. This form should be completed no later than the end of the first semester of enrollment in the MS Thesis program. This form is also a required element of MCEN 5208: Introduction to Research. Note that MS Thesis students are eligible to work with CU research advisors outside the Department of Mechanical Engineering; in such cases, the MS Thesis Research Expectations Form must still be completed in its entirety.
- **MS thesis hours:** 6 credits of MS thesis hours (MCEN 6959) must be completed, typically in the final two semesters of the program. Students are not able to register for MS thesis credits on their own and should submit a request for thesis hours through the Thesis/Dissertation Hours Enrollment Request Form.
- **Research Development Requirement:** A passing grade in MCEN 5208: Introduction to Research is required. This course is offered each fall semester and provides a strong foundation in a variety of topics related to research that will prove valuable both as a student and professional. Covered topics include ethics in research, literature review, and grant writing, among others. This requirement should be completed during the first fall semester.
- **Written thesis:** The written thesis must comply with Graduate School rules and procedures in terms of format and submission. Full details on formatting requirements are available here, and deadlines and resources to assist in finalizing your thesis are available here.

  Students are required to submit the full written thesis electronically at the ProQuest website. The timeline for these requirements is as follows:
  - The oral thesis defense must be passed about 2/3 into the last semester.
  - One week after the defense deadline, students must submit:
    - The written thesis, electronically; and
    - The physical signature page, signed by all committee members, to the Graduate School.

    Both of these items can be completed using the form provided here.

  Please see Chapter 3 for information on department support for dissertation printing costs..
- **Thesis defense:** Students must pass a thesis defense, which is a final examination on the thesis and related topics. In the defense, students are expected to explain their research clearly and concisely, and to discuss how it relates to other research in the field. This is an opportunity for recognition of completed MS Thesis research. It is also an opportunity for discussion and formal evaluation of the thesis.

  The thesis defense may occur before or after the final electronic submission of the written thesis to the Graduate School, but must take place prior to the end of the final semester. Failure to defend prior to the end of the proposed final semester may result in the need to register for additional course credits during another semester.

  All required forms should be submitted on time according to the following deadlines:
  - *To the Department:* The Master's Examination Report should be submitted to your graduate advisor at least 3 weeks prior to the defense.
  - *To the Committee:* The written thesis should be sent as a single pdf file by email to all members of the defense committee, as well as to the graduate advisors at megrad@colorado.edu, at least 1 week before the defense. This deadline is intended to allow the defense committee sufficient time to review the thesis and to formulate questions and feedback. Prior to the defense, students should

contact all members of the committee to assess their areas of interest and concerns. This will help students anticipate any questions that will be asked.

Students must be registered as full time, regular degree-seeking students during the semester in which they pass the examination. The examination is conducted by a committee appointed by the chair of the major department and approved by the Dean of the Graduate School, and consists of at least three people, two of which must be ME faculty.

The chair of the committee must have a regular or tenured Graduate Faculty appointment. The other committee members must have either regular or special Graduate Faculty appointments. Please contact the graduate advisors at megrad@colorado.edu as soon as you form your committee, and no later than 6 weeks prior to your examination, to verify that the necessary appointments are in place. It takes 2-4 weeks to process a faculty appointment. Students should submit a recent CV for any committee member who does not have a faculty appointment to the graduate advisors as soon as possible.

Students should coordinate scheduling the examination with the committee, and should schedule the examination for two hours. The examination is wholly oral and open to the public for the first portion of the examination. Students must prepare a professional oral presentation that covers what was written in the thesis. This presentation should be 45-50 minutes in length. This presentation shall be delivered at the final examination to the examination committee. The oral presentation portion of the examination is open to all students and faculty. Questions are entertained at the end of the presentation. The final part of the examination is closed to only the student and the examination committee. During this portion, questions are entertained that cover the field of concentration and related fields. More than one dissenting vote among the committee constitutes an unsatisfactory exam. A student who fails the exam may attempt it once more after a period of time determined by the committee.

More than one dissenting vote disqualifies the candidate in the final examination. The committee chair and a majority of the committee must be present on the Boulder campus for the examination.

5.4.3 Bachelor's-Accelerated Master's (BAM) Program

The BAM program offers currently enrolled CU undergraduate students the opportunity to receive both bachelor's and master's degrees in a shorter period of time. Students receive the bachelor's degree first, but begin taking graduate coursework as undergraduates, typically in their senior year. Because some courses are allowed to double count for both the bachelor's and the master's degrees, students receive a master's degree in less time and at a lower cost than if they were to enroll in a stand-alone master's degree program after completion of their baccalaureate degree. In addition, staying at CU to pursue a BAM program enables students to continue working with their established faculty mentors.

Admissions requirements and procedures for the BAM program are outlined in Chapter 2.

Early in the final semester of the undergraduate degree, students must apply to advance to graduate status by completing the Master's continuation form. This form is due by February 1 for spring graduates, March 1 for summer graduates, and October 1 for fall graduates. Students will matriculate into the master's program without additional departmental review provided they meet the basic continuation requirement of a 3.25 cumulative GPA. International students must have approval from International Student and Scholar Services (ISSS) prior to matriculation.

For their Master's degree, most students in the BAM program will complete the requirements of the Professional MS program outlined in Section 5.4.1. BAM students can pursue the MS Thesis program if admitted according to the application procedures enumerated in Section 2.7. If admitted to the MS Thesis program, BAM students should fulfill the MS Thesis degree requirements outlined in Section 5.

In order to achieve an accelerated BS/MS degree, students in the BAM program are eligible to use 6 graduate credit hours towards both the BS and MS degrees.

Substantial additional information on the BAM program can be found from the Office of the Registrar here, and

BAM program policies are available here.

5.4.4 Dual Engineering Management and ME Degree Program

A student who is pursuing the Professional MS degree in mechanical engineering and wishes to also obtain the Master's of Engineering in Engineering Management degree must apply internally and be admitted into the Engineering Management Program. Further details on admission requirements and procedures in the dual degree program are provided in Chapter 2.

In total, graduate students in the dual degree program must complete a total of 45 hours of coursework at the 5000 level or above, consisting of 21 credit hours from the Engineering Management Program (EMP) and at least 18 Department of Mechanical Engineering credit hours. Specific requirements are as follows:

- **Mechanical engineering coursework:** Students must complete at least 18 credits within mechanical engineering (i.e., MCEN courses). 6 additional credits must be completed and can be taken outside the department, if desired. The course MCEN 5208: Industry Skills is not required for students in the dual degree program, due to the overlap between the content of this course and the content of courses in Engineering Management.
- **Engineering management coursework:** The 21 credits required in engineering management typically consist of the following courses:
  - EMEN 5010: Introduction to Engineering Management
  - EMEN 5020: Finance and Accounting for Engineering Managers
  - EMEN 5030: Project Management; or EMEN 5031: Software Project Management; or EMEN 5405: Fundamentals of Systems Engineering
  - EMEN 5050: Leading Oneself
  - EMEN 5830: Special Topics: Engineering Communication
  - Two EMEN elective courses. Note that EMEN 5000: Engineering Analysis and EMEN 5005: Intro to Applied Statistics cannot be applied toward the Engineering Management degree.
- **Master's exam:** In Engineering Management, students must pass the master's exam in the final semester of classes or the semester after.

Additional up-to-date information on the dual degree program can be found on the the Engineering Management Program website.

5.4.5 Transfer Credit

Students may be eligible to transfer up to 9 hours of coursework to meet the Master's degree course requirements. More information is available on the second page of the Request for Transfer of Credit Form from the CU Graduate School. To transfer credits, students must fill out and submit this form to the graduate advisors at megrad@colorado.edu with official transcript(s) included.

Please note that requests for transfer credit can only be made after completing 6 credits of graduate level coursework at CU. These requests should be submitted as soon after completion of this 6 credit requirement as possible. Typically, this means that transfer of credit requests are processed during the second semester of study at CU. Additional information on transfer of credit requests is available in Section 6.7.

5.5 Application for Graduation

In order to graduate with the Master's degree, students must apply online through their myCU portal. On the "Student" tab, select the "Apply for Graduation" link under "Academic Resources".

The application for graduation is due a few weeks after the start of the desired graduation semester. Full details on requirements can be accessed by clicking on the appropriate program at this webpage, and deadlines are available by selecting the appropriate semester for graduation on this webpage. For all degree programs, the Candidacy Application for Advanced Degree must be submitted to the graduate advisors at megrad@colorado.edu prior to applying for graduation.

Detailed graduation information will be communicated to all students through the graduate student listserv at the beginning of each semester.

6 Curriculum

6.1 Deadlines

The Department adheres to the deadlines and calendar established by the Office of the Registrar. Students can find these dates for the current and future semesters here. The primary deadlines to be aware of, with dates that will vary by semester, are as follows:

- **Last day to add a class:** After this date, students can only be enrolled pending a petition to the Office of the Registrar, submitted by the Department on behalf of the student. Such requests will only be entertained in exceptional circumstances. This date is typically during the second week of the semester.
- **Tuition and fees payment due:** Students must pay tuition and fees, or enroll in a payment plan, by this date. This date is typically the day following the deadline for the last day to add a class.
- **Last day to drop a class:** After this date, students choosing to drop a course will receive a withdrawal (i.e., grade of 'W') on their transcripts; tuition for dropped courses will not be refunded. This date is typically during the third week of the semester.

Students should familiarize themselves with these dates, since it can be difficult or impossible to add/drop classes after the deadlines.

6.2 Adding and Dropping Courses

As noted above, students should add and drop all courses within their enrollment window, which is determined by the Registrar's office. Some courses require special application; in those cases, application details will be communicated in advance of the enrollment period via the grad student listserv.

Thesis, dissertation and independent study credits can only be added by the Graduate Advisor. Independent study credits will be automatically added upon approval of the independent study petition, as described in Section 6.5. Thesis and dissertation hours should be requested via the Thesis/Dissertation Hours Enrollment Request Form prior to the start of the semester.

Students who wish to drop a course after the drop deadline will be required to provide a letter of explanation stating why they would like to drop the course. In order to drop a class after the drop deadline has passed, students are required to petition the Dean and provide documentation showing that there were extenuating circumstances beyond their control (such as illness, injury, a death in the family, etc.) that occurred after the drop deadline, preventing the student from attending/participating in the course for which they were registered. Please consult your graduate advisor prior to dropping a course after the drop deadline.

Students who wish to withdraw from all classes should consult the Registrar's Office website here.

6.3 Transcripts

Official transcripts for current and previous graduate students can be ordered online from the Office of the Registrar here. Unofficial transcripts can be downloaded anytime by students through the educational portal.

6.4 Certificates

Both degree seeking and non-degree students have the option to pursue a graduate certificates in mechanical engineering. Admissions procedures and additional information can be found in Section 2.8.1. Currently we have one established certificate program in our department, but more will be added soon.

6.4.1 Biomedical Engineering

The Biomedical Engineering Certificate trains next-generation professional engineers to interface engineering and medicine with design and problem solving to improve human health.

9 credit hours of graduate level coursework will be required to complete the certificate program with grades of at least a B in each course. A minimum GPA of 3.0 is required to remain in good academic standing.

6.5 Independent Study

An independent study course is defined as research study requiring a high level of self-directed learning. This learning requires students to read, conduct research, and complete written examinations, reports, projects, research papers, portfolios, or similar assignments that are designed to measure competency in the stated objectives. This work may be experiential, directed reading, or independent research supervised by a faculty member and approved by the mechanical engineering graduate chair.

6.5.1 Guidelines

A number of activities are specifically prohibited as independent study work. Included here are such activities as internships, volunteer or paid work in a university department, volunteer work of other kinds, work in a business, extra work in a class, and work completed elsewhere. Strictly prohibited are independent study as a substitute for a regular course offering. Independent study will normally consist of directed research which leads to the preparation of a substantive presentation of findings, usually in the form of a written paper or report. Any variation on this format must be approved by the Department graduate committee.

University rules do not normally allow Independent Study credit for internship experiences, work-study or hourly pay work done in departments, or for work also compensated by a salary. In general, an independent study should not be used for resolving scheduling conflicts, making up failed classes or alleviating faculty teaching loads.

6.5.2 Requirements and Eligibility

The following minimum criteria must be met to ensure the overall outcomes of the educational experience, the success of the students, and compliance with accreditation standards:

- Students who take independent studies must have a minimum cumulative GPA of 3.25.
- The independent study must include comprehensive objectives in a written form.
- The independent study must demonstrate the relevance and appropriateness to the program outcomes.
- The independent study must promote a high level of self-directed learning.
- The independent study must engage students to interact with the instructor throughout the course.

6.5.3 Enrollment Procedure

The student will develop a plan or idea for independent study and will work with a faculty member to determine the feasibility and supervision of the class.

The student and the faculty member will complete the Independent Study Agreement Form including, but not limited to, the following information:

- Course description and area of study, including number of credits to be issued (1 credit hour is approximately equal to 40 clock hours of proposed independent study activity per semester).
- Learning objectives and outcomes.
- Approach to be used (directed reading, instructions and supervision, and/or lab experience, exercises and projects, etc.)
- Information on textbooks, references, and reading materials.
- Means of communication between student and faculty member throughout the course of independent study.
- Means of evaluation (one or more), typically consisting of a tangible product such as a project, presentation, written review of the literature, homework assignments or exams.
- Guidelines, schedules, benchmarks, milestones, or weekly task breakdowns throughout the semester.

When an independent study is designed and proposed, the rationale for the number of credits awarded by the course should meet the following criteria:

- 1 semester credit hour for each 40 clock hours of documented independent study activities.
- Students may only count a combined maximum of 6 credits of independent study and internship for credit toward their degree.

The completed Independent Study Agreement Form should be submitted no later than one week prior to the course add deadline, which can be found here. Upon approval of the independent study by the graduate committee, the graduate advisor will add the independent study credits to the student's schedule.

6.5.4 Documentation and Assessment

Through the course of an independent study, it is the student's responsibility to communicate with the instructor and document time spent on the independent study. Activities that constitute time spent on an independent study include, but are not limited to: reading, conducting research, completing written examinations, reports, projects, research papers, portfolios and homework assignments.

To ensure proper documentation, a final report or presentation slides should be provided to the graduate advisors at the end of the semester. This can be accomplished by filling out the Independent Study Completion Form, which also includes a brief summary of the main activities.

6.6 Internship for Credit

This course provides students with direct access to rich learning experiences that can be provided outside of the regular classroom where a wide variety of a coursework from multiple classes is synthesized and applied in ways and/or at scales that are not possible in a classroom setting.

Students will demonstrate expertise and integrate foundational concepts in engineering, project, and team skills during the design, development, and delivery activities in an engineering-related industrial project setting.

This course will also prepare students for professional careers in engineering-related industries.

Note that while a faculty advisor is required for each student completing the internship for credit course, ME faculty and the grad program are not responsible for organizing internships.

6.6.1 Requirements and Eligibility

The following requirements and eligibility apply to the internship for credit course:

- All internships for credit require a minimum of 150 contact hours to receive 3 credits towards degree requirements (or, 40-55 hours of work per credit).
- Students must have completed at least 1 semester in the graduate program before they can take the internship course.
- Students must have at least a 3.25 GPA to apply. Continued performance at this level is a prerequisite for

beginning an internship experience.
- Students may only count a combined maximum of 6 credits of independent study and internship for credit toward their degree; if needed, students can take the internship for credit class multiple times, but can only count it once toward their degree requirements.
- PhD, MS Thesis, Professional MS, and BAM students can take the course.
- Both paid and unpaid internships are permitted in the internship for credit course.
- Regular tuition and fees are required for the course.

Additional questions regarding requirements and eligibility should be directed to the graduate advisors.

6.6.2 Enrollment Procedure

This course requires an application process that must be completed and approved before the internship takes place. This application requires the following:

1. Specify details of the internship;
2. Specify and justify the specific academic goals of the internship;
3. Specify a contact at the company who will ensure the academic components of the internship are delivered;
4. Specify an ME faculty member who has agreed to review the reports generated by the student during the internship; it is this faculty member who will ultimately provide the student with a grade for this class.

Applications will be submitted via the Google form here, and students must also submit the impact of an internship on financial aid and/or scholarship form. International students must have their internship approved by an international student advisor before the first day of work.

Applications must be received at least one week before the start of the semester.

6.6.3 Documentation and Assessment

The grading approach and assignments will be determined by the faculty advisor. As an example:

- The course grade is based on weekly progress reports submitted via Canvas with information on the following topics:
  1. Summary of internship activities for the past week, including notable tasks and accomplishments;
  2. Work plan for the following week, including an itemized list of objectives;
  3. Specific concerns or challenges related to the internship (enter N/A if there are none).
- A one-on-one interview will be held with the instructor halfway through the course, and students will give a 20 min final presentation on their internship experience at the end of the semester, with 10 mins for questions and discussion.

Regardless of the grading approach and assignments agreed upon by the advisor and student, a student evaluation of the experience is due by the grade submission deadline of the term they are enrolled in. This evaluation should be completed using this form.

6.7 Transfers of Credit

To request transfer credit, graduate students should complete and submit the Request for Transfer of Credit Form from the CU Graduate School. To transfer credits, students must fill out and submit this form to the graduate advisors at megrad@colorado.edu. An official transcript(s) must be included with the request.

Please note that requests for transfer credit can only be made after completing 6 credits of graduate level coursework at CU. These requests should be submitted as soon after completion of this 6 credit requirement as possible. Typically, this means that transfer credit requests are processed during the second semester of study.

Transfer credits from accredited institutions are accepted by CU only after approval by the graduate chair and under the special conditions outlined below. Transfer credit is defined as any credit earned at another accredited institution, credits earned on another campus of the CU system, or credits earned as a non-degree student

within the CU system. Students seeking a degree from CU must complete the majority of their course work while enrolled in a graduate program as a degree seeking student.

The following rules apply to transferring credit to the CU Department of Mechanical Engineering:

1. The maximum amount of work that may be transferred to CU depends upon the graduate degree sought. Master's students may transfer up to 9 hours, while PhD students may transfer up to 21 hours.
2. Work already applied toward a graduate or undergraduate degree received from CU or another institution cannot be accepted for transfer toward another graduate degree of the same level at CU. In addition, work completed for a doctoral degree may not be applied toward a subsequent master's degree.
3. All courses accepted for transfer must be graduate level courses. The course grade must be B or higher. Transfer course work which is to be applied to a graduate degree at CU and was completed more than 5 years prior to being accepted to the program shall be evaluated by the Department as to current relevance and applicability to the degree requirements. At the discretion of the Department, a student may be asked to validate transfer credits prior to approval.
4. Credit may not be transferred until the student has completed 6 credits of graduate level course work as a degree-seeking student on the CU campus with a 3.0 GPA. Transferred credits do not reduce the minimum registration requirement but may reduce the amount of work to be done in formal courses.
5. With the exception of students enrolled in the BAM or BS/MS programs, seniors at CU Boulder may transfer a limited amount of graduate level work (up to 9 semester hours) provided such work:
    - Is completed with a grade of B or above at CU Boulder;
    - Comes within the five year course time limit;
    - Has not been applied toward another degree;
    - Is recommended for transfer by the department concerned, and such transfer is approved by the Dean of the Graduate School.

6.8 Curriculum Changes

Students seeking to waive a curriculum requirement or substitute a course should submit a petition to the Graduate Committee using Graduate Committee Petition. The petition should contain the reason(s) for the request, i.e. what action the student is requesting the Graduate Committee to take, and include detailed information about why the request should be approved. Supplementary materials such as course descriptions or syllabi may also be included. All petitions should be routed through the graduate advisor.

6.9 Course Repetition

A student who receives a grade of C+ or lower can request to retake the course for grade replacement. Full details and requirements are available on the registrar website.

6.10 Change of Record

Change of record requests are required for past-term student record changes and for current-term enrollment requests after add/drop deadlines. Some examples where a change of record request should be made include:

- Any academic record change after the last day of classes (e.g., add, drop, change grading basis or variable credits, expunge, etc.)
- Add a student to a class after the Monday before finals. In such cases, the change of record request must include the student's final grade, because the student will not appear on the grade roster.

Change of record requests can only be made with the graduate advisors and consent of the graduate chair. The department must submit appropriate documentation directly to the Registrar's Office. This office will not accept a student-delivered change of record request. Please reach out to the graduate advisors with any questions about this process.

6.11 Dissertation/Thesis Hour Level Change Requests

MS Thesis students who are admitted to the PhD program prior to completing the MS degree can petition the

graduate committee to change up to 6 thesis hours to dissertation hours by submitting a Graduate Committee Petition. The petition should demonstrate that the research completed while enrolled in thesis hours directly relates to the proposed dissertation research.

Similarly, PhD students who switch to the MS Thesis program may petition the graduate committee to change up to 6 dissertation hours to thesis hours by submitting a Graduate Committee Petition. The petition should demonstrate that the research completed while enrolled in dissertation hours directly relates to the proposed thesis.

6.12 Auditing Courses

Degree seeking students cannot audit courses. Students can register for NC (no credit), but will need to pay full price for the course. Please note that for students on a TA or RA appointment, the appointment will not cover the tuition cost of a course taken for no credit.

6.13 Grades of 'Incomplete'

To receive a grade of "I" (or incomplete), the student must receive the consent of the instructor and be able to demonstrate that for documented reasons beyond the student's control, the student was unable to complete course requirements during the semester enrolled. Students are given one year to complete the requirements for the course and receive a letter grade; after one year the incomplete grade automatically changes to an "F".

6.14 4000/5000 Level Courses

The CU Graduate School requires that there be a difference between 4000 and 5000 level courses that are taught as a combined 4000/5000 section. Students registered at the 5000 level are taking the course for graduate level credit, and thus the course expectations of that student must be at the graduate level. Conversely, students registered at the 4000 level are taking the course for undergraduate level credit, and thus the course expectations must be at the undergraduate level.

It is advised that the course instructor keep track of the course requirement differences between the 4000 and 5000 level students. An ideal location to document this difference is in the course syllabus. In recent years there have been instances where a student requests changing course credit from 4000 to 5000 level, or vice-versa. The University allows for this change if the student's grade can be adjusted (or additional requirements met) per documentation provided by the course instructor. One example is where a BS/MS student enrolls in a course at the 4000 level, and after completion requests a change to 5000 level, due to some unforeseen event. In this example, the course instructor is approached to determine a grade change, or asked if additional coursework needs to be completed. While it is up to the course instructor on how to proceed, having a documented difference that can be referenced can save the course instructor significant time and hassle, in addition to maintaining Graduate School requirements.

Course instructors should adjust their course requirements as to best fit their course. A graduate level course generally encourages deeper thought, additional workload, and/or higher expectations of the student. With that in mind, a few examples (non-exhaustive), or suggested differences that could be used to distinguish between 4000 and 5000 level students are:

- Additional project requirements for 5000 level students
- Additional exam problems for 5000 level students
- Additional reading assignments and evaluations for 5000 level students
- Additional reports, homework, or other measure of student performance for 5000 level students
- Inclusion of a teaching role for the graduate students

6.15 Grievance Procedures

The Graduate School established revised grievance procedures, effective April 1, 2019, that can be found here: Graduate School Grievance Procedures. These procedures are intended to provide a process by which graduate students can communicate concerns related to academic issues or academic conflicts. An additional brief

guide is available at https://www.colorado.edu/policies/student-appeals-complaints-grievances-brief-guide. Should you need any assistance with these procedures, please make sure to reach out to your Graduate and/or Faculty advisor, where appropriate.

Summary of Changes

A

A.1 October 15, 2019

The version of the Graduate Handbook dated October 15, 2019 (filename MEGraduateHandbook_101519.pdf) is the baseline version of the handbook that codifies pre-existing policies and procedures in the Department of Mechanical Engineering Graduate Program and makes the following changes:

- A new process to address internal applications and changes of program (e.g., from Professional MS to PhD degree) is outlined in Section 2.7. Additionally, details are provided in this section on the process for applying to the PhD program both with and without the expectation of Department funding as a Teaching or Research Assistant.
- Of the 30 course hours required by PhD students to graduate, 9 of these hours must be from 5000-level courses from the CU Department of Mechanical Engineering (i.e., MCEN courses), as described in Section 4.4.1. Previously there was no required minimum number of MCEN course hours for the PhD degree in Mechanical Engineering.
- As outlined in Section 4.4.3, all PhD students are required to take MCEN 5020 Methods of Engineering Analysis and to pass with a grade of B- or higher. Students receiving a grade below B- in MCEN 5020 must retake the course. This course satisfies the "Mathematical Proficiency Requirement" for PhD students and there is no longer a written "test out" or "preliminary" methods exam.
- The Research Expectations Form must be completed by both PhD and MS Thesis students once a research advisor has been found, as outlined in Sections 4.4.4 and 5, respectively.
- The "Research Development Requirement" for PhD and MS Thesis students now simply requires successful completion of MCEN 5208: Introduction to Research, as described in Sections 4.4.5 and 5. This requirement replaces the previous "Professional Development Workshop" (PDW) requirement, although PDWs will still be tracked for more senior PhD students (i.e., those matriculating prior to Fall 2019) who remain under the old system.
- For PhD students, comprehensive exam reports and written dissertations must be sent to the exam committee and the ME Graduate Advisors no later than two weeks before the exam date, as outlined in Sections 4.4.8 and 4.4.10. Previously, this requirement was not rigorously enforced, but students who fail to meet this deadline may now be asked to delay their oral examination to meet the two week requirement.
- For MS Thesis students, written theses must be sent to the exam committee and the ME Graduate Advisors no later than one week before the exam date, as outlined in Section 5. Previously, this requirement was not rigorously enforced, but students who fail to meet this deadline may now be asked to delay their

oral examination to meet the one week requirement.
- The oral public presentation at the PhD comprehensive exam and dissertation defense, as well as the MS Thesis defense, should be between 45-50 mins in length, as detailed in Sections 4.4.8, 4.4.11, and 5. Previously, there was no recommendation for minimum presentation length.
- The numbers of Professional Development Program (PDP) required seminars have been updated to:
  - **PhD:** 25 PDP seminars
  - **Professional MS:** 15 PDP seminars
  - **MS Thesis:** 10 PDP seminars
  - **BAM:** 10 PDP seminars
  - **Dual Degree in Engineering Management and ME:** 15 PDP seminars

Each of these changes have been discussed and approved by the Department of Mechanical Engineering Graduate Committee during the Fall 2019 semester.

A.2 May 28, 2020

The version of the Graduate Handbook dated May 28, 2020 (filename MEGraduateHandbook_052820.pdf) includes updated oral preliminary exam concept inventories, as well as a link to prior exams, in the new Appendix E.2.

A.3 August 19, 2020

The version of the Graduate Handbook dated August 19, 2020 (filename MEGraduateHandbook_081920.pdf) includes typo corrections and clarifications throughout, updates to personnel and contact info in Chapter 1, removes the GRE requirement from Chapter 2, provides further information on summer fellowships in Chapter 3.

A.4 September 22, 2021

The version of the Graduate Handbook dated September 24, 2021 (filename MEGraduateHanbook_092421.pdf) includes typo corrections and clarifications throughout as well as the following more substantial changes:

- Updates to personnel and contact info in Chapter 1.
- A description of the joint mechanical and environmental engineering degree program in Section 2.2.4.
- A new Section 2.3.4 outlining eligibility for application fee waivers.
- A description of the English language screening test for international students serving as TAs in Section 3.5.1.
- The professional development requirement has been removed from Chapter 4 describing PhD degree requirements, and the new research development requirement is described.
- The professional development requirement in Chapter 5 describing Professional MS degree requirements has been changed to consist only of a passing grade in MCEN 5208: Industry Skills.
- The professional and research development requirement in Chapter 5 describing MS Thesis degree requirements has been changed to consist only of a passing grade in MCEN 5208: Introduction to Research.
- A description of the new internship for credit course has been added to Chapter 6.
- Students are now only allowed to count 6 credit hours total of independent study and internship for credit courses towards their degrees, as described in Chapter 6.
- Appendix C has been added with upcoming class schedules and instructors.
- Appendix D has been added with descriptions of ME graduate courses.
- Additional oral preliminary exam guidelines have been included in Appendix E.

A.5 February 11, 2022

The version of the Graduate Handbook dated February 11, 2022 (filename MEGraduateHanbook_021122.pdf) includes updated graduate chair contact info in Chapter 1, new RA/TA pay rates in Chapter 3, a description of the research preliminary exams in Appendix F, a resource document for faculty in Appendix H, as well as other

typo corrections and clarifications throughout.

A.6 May, 2022

Several updates applied to make minor adjustments to Oral Prelim concept inventories, update exam leads, update exam format, and to indicate the planned phase-out of the BioM^3 exam.

B Forms

B.1 Internal Mechanical Engineering Forms

- Application for department support
- Bachelor's Accelerated Master's (BAM) plan of study certification
- Change of program form
- Grad program petition
- GRE Waiver Form
- Hourly Employment Interest Form
- Independent study agreement form
- Independent study completion form
- Internship for credit enrollment form
- Internship for credit financial impact form
- Internship for credit final evaluation form
- Research expectations form (MS Thesis)
- Research expectations form (PhD)
- Research preliminary exam form
- Student of the month
- Teaching assistant expectations form
- Thesis/Dissertation hours enrollment request form

B.2 Graduate School Forms

- Bachelor's Accelerated Master's (BAM) continuation form
- Bachelor's Accelerated Master's (BAM) intent form
- Candidacy application for advanced degree
- Concurrent BS/MS degree program supplement to the application for admission to candidacy
- Concurrent BS/MS certificate of completion of the requirements for the Bachelor's degree
- Graduate program application
- Graduate student request for extension of time limit
- MS Examination Report
- PhD Examination Report
- Request for Transfer of Credit form

ME Graduate Course Schedule

The following schedule of courses will be updated as new information becomes available, and students with questions about current or upcoming courses should reach out to megrad@colorado.edu with any questions. The instructor of record is listed in italics after each course, and course descriptions are provided in Appendix D.

C.1 Fall 2021

- MCEN 5020: Methods of Engineering Analysis *(Peter Hamlington, peh@colorado.edu)*
- MCEN 5021: Introduction to Fluid Dynamics *(Jeremy Koch, jeremy.koch@colorado.edu)*
- MCEN 5023: Solid Mechanics *(Francois Barthelat, francois.barthelat@colorado.edu)*
- MCEN 5032: Sustainable Energy *(Jana Milford, jana.milford@colorado.edu)*
- MCEN 5055: Advanced Product Design *(Janet Tsai, janet.tsai@colorado.edu)*
- MCEN 5065: Graduate Design 1 *(Gregory Whiting, gregory.whiting@colorado.edu)*
- MCEN 5115: Mechatronics 1 *(Derek Reamon, derek.reamon@colorado.edu)*
- MCEN 5117: Anatomy & Physiology for Engineers *(Jessica Fitzgerald, jessica.fitzgerald-1@colorado.edu)*
- MCEN 5127: Biomedical Ultrasound *(Nick Bottenus, nick.bottenus@colorado.edu)*
- MCEN 5151: Flow Visualization *(Scott Wieland, scottwieland23@gmail.com)*
- MCEN 5152: Combustion *(Nicole Labbe, nicole.labbe@colorado.edu)*
- MCEN 5174: Failure of Engineering Materials *(Todd Murray, todd.murray@colorado.edu)*
- MCEN 5208: Introduction to Research *(Hope Michelsen, hope.michelsen@colorado.edu)*
- MCEN 5228: Fracture Mechanics *(Rong Long, rong.long@colorado.edu)*
- MCEN 5228: Introduction to Nanoscale Transport *(Longji Cui, longji.cui@colorado.edu)*
- MCEN 5228: Linear Systems *(Xudong Chen, xudong.chen@colorado.edu)*
- MCEN 5228: Advanced Dynamics *(Sean Humbert, sean.humbert@colorado.edu)*
- MCEN 5228: Lean/Six Sigma Manufacturing *(Jenifer Blacklock, jenifer.blacklock@colorado.edu)*
- MCEN 5228: Design of Coffee *(Carmen Pacheco-Borden, carmen.pachecoborden@colorado.edu)*
- MCEN 5228: Ceramics *(Rishi Raj, rishi.raj@colorado.edu)*
- MCEN 5228: Microfluidics *(Xiaoyun Ding, xiaoyun.ding@colorado.edu)*
- MCEN 5228: Feedback Control *(Shalom Ruben, shalom@colorado.edu)*
- MCEN 5228: Modeling Human Movement *(Alaa Ahmed, alaa.ahmed@colorado.edu)*
- MCEN 5228: Mechanics of Soft Matter *(Franck Vernerey, franck.vernerey@colorado.edu)*
- MCEN 5228: Project Based Learning in Rural Schools *(Daniel Knight, daniel.knight@colorado.edu)*

- MCEN 5636: Micro-Electro-Mechanical Systems *(Victor Bright, victor.bright@colorado.edu)*
- MCEN 6228: Wetting, Adhesion, Friction *(Yifu Ding, yifu.ding@colorado.edu)*

C.2 Spring 2022

- MCEN 5022: Classical Thermodynamics *(Jeremy Koch, jeremy.koch@colorado.edu)*
- MCEN 5024: Materials Chemistry & Structures *(Conrad Stoldt, conrad.stoldt@colorado.edu)*
- MCEN 5042: Grad Heat Transfer *(Longji Cui, longji.cui@colorado.edu)*
- MCEN 5044: Mechanical Behavior of Materials *(Rishi Raj, rishi.raj@colorado.edu)*
- MCEN 5045: Design for Manufacturability *(Dan Riffell, daniel.riffell@colorado.edu)*
- MCEN 5055: Advanced Product Design
- MCEN 5075: Grad Design 2 *(Gregory Whiting, gregory.whiting@colorado.edu)*
- MCEN 5117: Anatomy & Physiology *(Wei Tan, wei.tan-1@colorado.edu)*
- MCEN 5125: Optimal Design *(Shalom Ruben, shalom@colorado.edu)*
- MCEN 5131: Air Pollution Control Engineering
- MCEN 5133: Intro to Tissue Biomechanics *(Virginia Ferguson, virginia.ferguson@colorado.edu)*
- MCEN 5135: Wind Energy *(Roark Lanning, rola5752@colorado.edu)*
- MCEN 5161: Aerosols *(Marina Vance, marina.vance@colorado.edu)*
- MCEN 5173: Finite Element Analysis *(Jianliang Xiao, jianliang.xiao@colorado.edu)*
- MCEN 5194: Energy Conversion & Storage *(Se-Hee Lee, sehee.lee@colorado.edu)*
- MCEN 5208: Industry Skills
- MCEN 5228: Design for Inclusion *(Janet Tsai, janet.tsai@colorado.edu)*
- MCEN 5228: Bioinspired Robotics *(Kaushik Jayaram, kaushik.jayaram@colorado.edu)*
- MCEN 5228: Automated Mechanical Design *(Robert MacCurdy, maccurdy@colorado.edu)*
- MCEN 5228: Computational Fluid Dynamics *(Debanjan Mukherjee, debanjan@colorado.edu)*
- MCEN 5228: Materials & Devices in Medicine *(Wei Tan, wei.tan-1@colorado.edu)*
- MCEN 5228: Biofluids at the Macro Scale *(Debanjan Mukherjee, debanjan@colorado.edu)*
- MCEN 5228: Regenerative Bio & Tissue Repair *(Sarah Calve, sarah.calve@colorado.edu)*
- MCEN 5228: Mechanics of Cancer *(Maureen Lynch, maureen.lynch@colorado.edu)*
- MCEN 5228: Thin Film Materials *(Jianliang Xiao, jianliang.xiao@colorado.edu)*
- MCEN 5228: Mechanics of Snow *(Francois Barthelat, francois.barthelat@colorado.edu)*
- MCEN 5228: Food Engineering *(Carmen Pacheco-Borden, carmen.pachecoborden@colorado.edu)*
- MCEN 5228: Feedback Control *(Lucy Pao, lucy.pao@colorado.edu)*
- MCEN 5228: Environmental Law for Engineers *(Jana Milford, jana.milford@colorado.edu)*
- MCEN 5228: Energy Materials Characterization *(Chunmei Ban, chunmei.ban@colorado.edu)*
- MCEN 5228: Mechatronics 2 *(Derek Reamon, derek.reamon@colorado.edu)*
- MCEN 5228: Nanomaterials *(Xiaobo Yin, xiaobo.yin@colorado.edu)*
- MCEN 5228: Thermofluids Lab *(Jeffrey Knutsen, jeffrey.knutsen@colorado.edu)*
- MCEN 5228: PBL in Rural Schools *(Daniel Knight, daniel.knight@colorado.edu)*
- MCEN 6001: Reacting Flows *(Peter Hamlington, peh@colorado.edu)*
- MCEN 6184: Structures/Properties of Polymers *(Yifu Ding, yifu.ding@colorado.edu)*

ME Graduate Course Catalog

D.1 Permanent Courses

MCEN 5020: **Methods of Engineering Analysis**
Studies selected topics from linear algebra, ordinary differential equations, and Fourier series. Assigns computer exercises. Correlates with analysis topics in other mechanical engineering graduate courses, and emphasizes applications.

MCEN 5021: **Introduction to Fluid Dynamics**
Focuses on physical properties of gases and liquids, and kinematics of flow fields. Analyzes stress; viscous, heat-conducting Newtonian fluids; and capillary effects and surface-tension-driven flow. Other topics include vorticity and circulation, ideal fluid flow theory in two and three dimensions, Schwartz-Christoffel transformations, free streamline theory, and internal and free-surface waves.
Prerequisite of knowledge comparable to that gained in MCEN 3021. Corequisite of MCEN 5020.

MCEN 5022: **Classical Thermodynamics**
Accelerated graduate level course on classical thermodynamics from the mechanical engineering perspective, focusing on the fundamental principles of thermodynamics and their applications to practical systems. Course topics include first and second laws of thermodynamics, entropy and availability, cycle analysis, thermodynamic properties of pure substances and mixtures, property relations, chemical reactions and chemical availability, and energy systems analysis.

MCEN 5023: **Solid Mechanics**
Introduces stress, strain and motion of a continuous system. Discusses material derivative; fundamental laws of mass, momentum, energy and entropy; constitutive equations and applications to elastic and plastic materials.
Prerequisite of knowledge comparable to that gained in MCEN 2063. Corequisite of MCEN 5020.

MCEN 5024: **Materials Chemistry and Structures**
Provides graduate level students with a comprehensive overview of the chemistry and structure of material systems, with a focus on chemical bonding., the resulting material structures and their properties. This course is intended to become one of the four core courses offered in the new Materials Science curriculum. Course topics include: bonding in solids, crystalline and amorphous states, basic group theory, diffraction, metals and alloys, ceramics, and an intro to materials characterization.

MCEN 5032: **Sustainable Energy**
Examines sustainability of our current energy systems, including transportation, using environmental and economic indicators. Uses systems analysis that addresses energy supply and demand. Explores the science and technology as well as environmental and economic feasibility of efficiency measures and renewable energy technologies. Additional emphasis is given to the global nature of the challenges and the potential for locally optimal solutions.
Prerequisite of knowledge comparable to that gained in MCEN 3012, MCEN 3021, and MCEN 3022.

MCEN 5042: **Graduate Heat Transfer**
Studies development of equations governing transport of heat by conduction, convection, and radiation, and their solution. Includes analytical and numerical solution of initial and boundary value problems representative of heat conduction in solids. Describes heat transfer in free and forced convection, including laminar and turbulent flow. Also involves radiation properties of solids, liquids, and gases and transport of heat by radiation.

MCEN 5044: **Mechanical Behavior of Materials**
This introductory-level graduate course incorporates relevant aspects of materials science, solid mechanics, thermodynamics and mathematics, and applies them to achieve a fundamental understanding of the mechanical behavior of crystalline and non-crystalline engineering materials.

MCEN 5045: **Design for Manufacturability**
Topics include general design guidelines for manufacturability; aspects of manufacturing processes that affect design decisions; design rules to maximize manufacturability; economic considerations; value engineering and design for assembly. Presents case studies of successful products exhibiting DFMA principles.

MCEN 5055: **Advanced Product Design**
Introduces the processes and methods for designing products. Course content includes: need finding and need specification, ideation and idea selection, design thinking, user-centered design, human factors, sketching, prototyping, user feedback, design communication, design for manufacturing, materials selection, and intellectual property. Teams of 3-4 students will design and build a novel product throughout the semester.
Prerequisite or corequisite or MCEN 4045 for undergraduate students. This course is enrollment limited. Please contact megrad@colorado.edu for more details.

MCEN 5065: **Graduate Design 1**
First part of a two-course graduate product design experience in mechanical engineering. Covers problem definition and specifications, determining design requirements, user feedback, alternative design concepts, engineering analysis, concept prototypes and CAD drawings. Students make several oral design reviews, a final design presentation and prepare a written report. Entails a team product design, fabrication and testing cycle of sponsored project.
Prerequisite of MCEN 5055. Requires instructor permission to enroll.

MCEN 5075: **Graduate Design 2**
Second part of two-course graduate product design experience in mechanical engineering. Includes refinement of prototype, design optimization, fabrication, testing, and evaluation. Students orally present the final design and prepare a written report and operation manual for the product. Entails a team product design, fabrication, and testing cycle of a sponsored project, leading to a fully-functional product.

MCEN 5115: **Mechatronics & Robotics 1**
Focuses on design and construction of microprocessor-controlled electro-mechanical systems. Lectures review critical circuit topics, discuss sensor and actuator component selection, microprocessor selection and programming, robotic systems, systems integration, and design strategies for complex, multi-system devices. Lab work reinforces lectures and allows hands-on experience with mechatronic design. Students must design

and build an autonomous robotic device.
Prerequisite of knowledge comparable to that gained in ECEN 3010 and CSCI 1300.

MCEN 5117: **Anatomy & Physiology for Engineers**
Explores human physiological function from an engineering, specifically mechanical engineering, viewpoint. Provides an introduction to human anatomy and physiology with a focus on learning fundamental concepts and applying engineering (mass transfer, fluid dynamics, mechanics, modeling) analysis.

MCEN 5125: **Optimal Design**
Learn how to formulate engineering optimization problems into mathematical forms that can be solved by standard software tools to find the "best" solution. Applications such as the minimum cost mechanical design, wind farm power maximization, minimum energy control, operations research, classification via support-vector machine, and even a Sudoku solver will be explored using the tools learned.
Prerequisite of MCEN 3030 for undergraduate students and programming knowledge for graduate students.

MCEN 5127: **Biomedical Ultrasound**
Covers the design of ultrasound systems for medical imaging and therapy, including the physics of wave propagation, transducers, acoustic lenses, pulse-echo imaging and cavitation dynamics, with an emphasis on current topics in biomedical ultrasound. Includes lectures on theory, practice and special topics; a laboratory on wave propagation; oral presentations on current literature; and a design project.
Prerequisite of knowledge comparable to that gained in MCEN 3021.

MCEN 5131: **Air Pollution Control Engineering**
Introduces air quality regulations, physics and chemistry in the atmosphere, meteorology, and exposure. Examines methods for controlling major classes of air pollutants, including particulate matter and oxides of sulfur and nitrogen, as well as control technologies for sources such as coal power plants and motor vehicles. Requires interdisciplinary design projects.
Prerequisites of [MCEN3012 or GEEN3852 or AREN2110] and [MCEN3021 or CVEN3313] for undergraduate students. Comparable prerequisite knowledge required for graduate students.

MCEN 5133: **Introduction to Tissue Biomechanics**
Focuses on developing an understanding of the fundamental mechanical principles that govern the response of hard and soft biological tissue to mechanical loading. Specifically, covers mechanical behavior of biological materials/tissues, classical biomechanics problems in various tissues, the relationship between molecular, cellular and physiological processes and tissue biomechanics and critical analysis of related journal articles.
Prerequisites of MCEN 2024, MCEN 2063, and MCEN 3021 for undergraduate students. Comparable prerequisite knowledge required for graduate students.

MCEN 5151: **Flow Visualization**
Explores techniques for visualizing the physics of fluid flows including seeding with dyes, particles and bubbles, and shadowgraphy and schlieren. Reviews optics and fluid physics, especially atmospheric clouds. Assignments are student-driven, to individuals and mixed teams of graduates, undergraduates, engineering majors and photography/video majors. MCEN students who enroll in the ATLS, ARTS, or ARTF sections of this course will be dropped at the instructor's discretion.
Prerequisite of knowledge comparable to that gained in MCEN 3021.

MCEN 5152: **Introduction to Combustion**
Focuses on the mechanisms by which fuel and oxidizers are converted into combustion products. Application to practical combustion devices such as Otto, Diesel, gas turbine, and power plant combustion systems. Consideration of combustion-generated air pollution, fire safety, and combustion efficiency.
Prerequisite of knowledge comparable to that gained in MCEN 3012. Knowledge comparable to that gained in MCEN 3021 and MCEN 3022 is also recommended.

MCEN 5161: **Aerosols**
Aerosols (solid/liquid particles suspended in a gas) are ubiquitous. They come in many forms, often described as dust, fume, mist, smoke, smog, or fog and they can affect visibility, climate, as well as our health and quality of life. Understanding the aerosol properties enables us to comprehend the production, transport, and fate of atmospheric particulate pollutants. This course covers physical properties, behavior, and measurement and sampling of aerosols. This course introduces atmospheric aerosols and properties of their distributions, followed by fundamental descriptions of single particle dynamics and populations dynamics. Particle sampling, respiratory deposition, thermodynamics, electrical and optical properties are also covered.

MCEN 5173: **Finite Element Analysis**
The class is an introductory course of finite element analysis (FEA). It introduces the theory behind and applications of the finite element method as a general and powerful tool to model a variety of phenomena in mechanical engineering. It will cover the fundamental theory of FEA including FEA formulas for truss, beam, 2D and 3D elasticity problems, general theory and considerations of FEA. The lab session will give chances to apply the FEA tool to problems including structural mechanics, elasticity, and heat conduction.
Prerequisites of MCEN 2063 for undergraduate students. Comparable prerequisite knowledge required for graduate students.

MCEN 5174: **Failure of Engineering Materials**
Examines the fundamental concepts regarding the failure of engineering materials. Case studies are used to integrate a basic understanding of material failure mechanisms with analysis techniques and tools. Topics include the elastic properties (isotropic and anisotropic materials) and the origin of elastic behavior, viscoelasticity, plasticity (dislocation mechanisms, yielding criteria, strengthening mechanisms), creep, fracture and fatigue.
Prerequisite of knowledge comparable to that gained in MCEN 2024 and MCEN 2063.

MCEN 5194: **Energy Conversion and Storage**
Presents the fundamentals, principles and experimental techniques of electrochemistry, the background of ionic or electronic conduction of metal, semiconductor, inorganic and polymer materials, and applications in the areas of batteries, fuel cells, electrochemical double layer capacitors, electrochemical photonics, sensors and semiconductor electrochemistry.
Prerequisites of MCEN 2024 and MCEN 3032 for undergraduate students. Comparable prerequisite knowledge required for graduate students.

MCEN 5208: **Introduction to Research**
This course is required for any student planning to write a graduate thesis in mechanical engineering, including PhD and MS thesis students. A major educational objective for these students in the first year of graduate school is to learn how to conduct research, the ins and outs of getting a PhD/writing a thesis, and how to build a community with peers. This course covers each of these topics and, at the end of the semester, students will present a summary of their research and participate as an audience member in listening to the presentations of their peers.

MCEN 5208: **Industry Skills**
This class consists of a series of seminars, workshops, and projects focused on various topics relevant to careers in industry, including project management, engineering ethics, communication skills, technical writing, resume preparation, budget preparation and management, leadership styles and philosophies, and interview skills. This class is required for all students completing the professional MS degree in mechanical engineering, although students in other degree programs may also find this course to be useful career preparation.

MCEN 5294: **Feedback Control**
Introduction to fundamental principles and techniques for analysis and synthesis of feedback control systems in the time and frequency domains. Linearization, review of linear system response, frequency response, trans-

fer functions and Bode diagrams. Closed loop system analysis including root locus, Nyquist criterion, gain and phase margins. Compensation design with lead, lag and PID controllers. Translation of closed loop performance requirements into open loop constraints. Model uncertainty and robustness. Introduction to state space representations and state feedback control.
Prerequisite of knowledge comparable to that gained in MCEN 4043.

MCEN 5636: **Micro-Electro-Mechanical Systems**
Addresses micro-electro-mechanical systems (MEMS) modeling, design, and fabrication. Focus is on MEMS sensors and actuators due to significance of these devices in optics, medical instruments, navigation components, communications, and robotics.
Prerequisites of knowledge comparable to that gained in ECEN 3010 and MCEN 4043.

MCEN 6001: **Reacting Flows**
Provides an introduction to reacting flows and combustion. Covers chemical kinetics, including global and detailed mechanisms and the variable density flow equations are derived. Relevant non-dimensional parameters and limiting behaviors are discussed. The Rankine-Hugoniot relations are presented and various aspects of diffusion, kinetically dominated and balanced combustion are outlined. Flame structures are discussed, including laminar and turbulent flames, and the Burke-Schumann solution is outlined. The turbulent forms of the motion equations are derived, and the reactive scalar transport equation and mixture fraction variable are presented. The flamelet progress variable approach is outlined, including a comparison of steady and unsteady flamelet models. Specific topics in spray combustion, triple flames, solid-gas reactors and detonations are discussed.
Prerequisite of MCEN 5021.

MCEN 6184: **Structures and Properties of Polymers**
Emphasizes the relationships between molecular structures and macroscopic properties of polymers. Structural aspects include chain conformation, configuration, and the crystalline and amorphous states. Discusses physical, mechanical and dynamic properties with a focus on solution and phase behavior, transitions of bulk polymers, and rubber and viscoelastic behavior.
Prerequisite of intro-level polymer courses.

D.2 Special Topics Courses

MCEN 5228: **Lean/Six Sigma Manufacturing** *(Offered by Prof. Jeni Blacklock)*
This course focuses on Lean principles and Six-sigma methodologies for defining, measuring, analyzing, improving and controlling (DMAIC) processes in order to create more efficient processes. Skillsets that will be learned include; value stream maps, SIPOCS, statistical process control, GR&R studies, statistics, graphical representation, and Minitab. This course has shown to be successful in training your brain to think differently about processes through identifying wastes and improving processes to be more efficient. By the end of the class, you will have practiced these skillsets several times and should feel comfortable with implementing them in an industry setting. Students will be prepared to take the Lean Bronze certification and at least the Six-Sigma white-belt certification, depending on work experience, at the completion of this course.

MCEN 5228: **Design of Coffee** *(Offered by Prof. Carmen Pacheco-Borden)*
This class will serve as an introduction to how engineers use their disciplinary training to approach and solve problems outside of the traditional confines of their discipline, as illustrated by the roasting and brewing of coffee. In addition to focusing on the science and craftsmanship of making a cup of coffee from bean to cup, we will also study the global sourcing of coffee beans. We will examine farming practices to grow fair-trade and organic beans. The course will offer weekly hands-on experimental laboratories to demonstrate key engineering principles in subject areas such as heat transfer, mass transfer, thermodynamics, materials science, sustainability, water quality, biomedical engineering and device design evaluation. This class culminates in an engineering design competition where students design to make the best tasting coffee using the least amount

of energy.

MCEN 5228: **Ceramics** *(Offered by Prof. Rishi Raj)*
This class is driven by projects which are defined by scientific, technological and aesthetic applications of ceramics. Examples are The Hubble Telescope, Corning Ware, Atomic Force Microscope, Fine Arts, Lighting, Ceramic Gas Turbines, Solid Oxide Fuel Cell, Volcanoes, Lasers, Jewels and Petrified Wood. The plan is for small groups to focus on one topic and advance it through the semester through collective discussions, and where possible, developing a touch-and-feel demonstration. The grade will consider fundamental understanding of ceramics developed through project experience, and project performance.

MCEN 5228: **Intro to Microfluidics** *(Offered by Prof. Xiaoyun Ding)*
Microfluidics deals with the behavior of fluids in small scale. It is a highly multidisciplinary field at the intersection of engineering, physics, chemistry, biology, medicine, nanotechnology, and biotechnology. This course is designed for a wide audience in Engineering and Science. It covers the fundamentals and fabrication of microfluidic devices, and their applications, particularly in Lab on a Chip. It includes lectures, team presentations, and possibly one laboratory on microfluidic devices. Mastery will enhance your understanding of microfluidic technologies and their broad applications.
Prerequisite of knowledge comparable to that gained in MCEN 3021.

MCEN 5228: **Nanomaterials** *(Offered by Prof. Xiaobo Yin)*
Understand fundamentals of the materials sciences and solid state physics that are uniquely associated with nanostructures and nanomaterials. To understand how the properties of a nanomaterial, such as mechanic, electronic, optical, and magnetic properties, can be affected and even substantially tailored by the size, geometry, composition and the structure of the nanomaterial. Understand the fundamental concepts in the design, manufacturing, characterization and application of functional nano-materials/structures. Develop the skill to be conversant in the multiple disciplines that involve nanomaterials and be aware of the social, ethical and environmental impacts resulting from the involved nanotechnology.
Prerequisite of knowledge comparable to that gained in MCEN 2024.

MCEN 5228: **Modeling of Human Movement** *(Offered by Prof. Alaa Ahmed)*
Human movement analysis is used in a wide range of applications, from physical rehabilitation to sport training, human-robot interaction and animation. The course will provide a systematic overview of human movement on multiple levels of analysis, with an emphasis on the phenomenology amenable to computational modeling. Topics will include muscle physiology, movement-related brain areas, musculoskeletal mechanics, forward and inverse dynamics, optimal control and Bayesian inference, learning and adaptation. The focus will be on reaching and locomotion as representative human movements.
Prerequisites of knowledge comparable to that gained in MCEN 2043 and APPM 2360.

MCEN 5228: **Fracture Mechanics** *(Offered by Prof. Rong Long)*
This course will introduce fundamental concepts, analytical approaches, and experimental methods to characterize the fracture of solid materials. Topics to be discussed include: linear elastic analysis of 2D cracks, energy flows and criteria for elastic fracture, experimental methods for elastic fracture, application of fracture mechanics in adhesion, introduction to elastic plastic fracture, and nonlinear fracture mechanics of soft materials.

MCEN 5228: **Introduction to Nanoscale Transport** *(Offered by Prof. Longji Cui)*
This course covers the basic concepts and methods to understand nanoscale transport phenomena that are ubiquitous in microelectronics, nano-enabled renewable energy technology, heat transfer, nano-optics, Micro/Nano-Electro-Mechanical-Systems (MEMS/NEMS), as well as emerging quantum technologies. Relevant laboratory and real-world applications and examples will be discussed. Topics include basics of solid-state physics and quantum mechanics, nano-electronic transport, nanoscale heat transfer, experimental techniques and instrumentations for characterizing/testing nanoscale materials and devices.

MCEN 5228: **Linear Systems** *(Offered by Prof. Xudong Chen)*
Introduces the theory of linear systems, including vector spaces, linear mappings, structure of linear operators, state space descriptions of dynamic systems, stability, controllability, observability, state variable estimation and feedback control methods.
Prerequisite of knowledge comparable to that gained in APPM 2360. This is a challenging, graduate level course. Undergraduates should contact the course instructor prior to enrolling.

MCEN 5228: **Mechanics of Soft Matter** *(Offered by Prof. Franck Vernerey)*
This class will provide a general overview of fundamental concepts behind the mechanical behavior of soft matter. The term soft matter (which includes polymers, colloids, liquid crystals and surfactants, to name a few) is typically used to describe classes of materials whose structural unit is much larger than atoms, making their response more complex and often richer that of traditional solids. The objective of this class is to understand how chemical and mechanical forces between these small units yield macroscopic behaviors that one can observe in everyday life. Key engineering applications will also be discussed.
Prerequisite of knowledge comparable to that gained in MCEN 2063.

MCEN 5228: **Advanced Dynamics** *(Offered by Prof. Sean Humbert)*
This course covers advanced theory for formulating and analyzing dynamical systems, including Newtonian, Lagrangian and Hamiltonian methods. Additional topics include equilibria, stability, Lyapunov functions, limit cycles, conservation laws and basic bifurcation theory.

MCEN 5228: **Design for Inclusion** *(Offered by Prof. Janet Tsai)*
Are robots racist? Are algorithms oppressive? How do we end up with technologies that are optimized for some users, but scarcely meet the needs of others? In this era of upheaval and inequity, how should we be thinking about who benefits or who is harmed by a product? How can we as ethical engineers even begin to answer these questions? The Design For Inclusion (DFI) course will examine the ways modern inventions like apps, products, public infrastructures and educational systems are biased, and what we as socially conscious engineers and designers can and should do about it. Design approaches including universal design, participatory action research, and culturally responsive design will be explored through multiple hands-on projects with the goal of equipping all to become more capable designers for inclusion rather than exclusion. The DFI course will prepare students to analyze innovations and seek opportunities for change, reframing the way we think about technological advancement and the communities we serve with our designs.

MCEN 5228: **Bioinspired Robotics** *(Offered by Prof. Kaushik Jayaram)*
In this course, you will learn how to build robots by leveraging principles of bioinspired design. Specifically, bioinspired design views the process of how we learn from nature as an innovation strategy translating principles of function, performance and aesthetics from biology to human technology. Lectures will address the biomimicry design process from original scientific breakthroughs to entrepreneurial start-ups using cases studies that include gecko-inspired adhesives, robots that run, fly and swim, artificial muscles, computer animation, medical devices and prosthetics while highlighting health, the environment, and safety. Diverse teams of students will collaborate on, create, and present original bioinspired robotic devices as projects at the end of the course.

MCEN 5228: **Automated Mechanical Design** *(Offered by Prof. Rob MacCurdy)*
This course introduces computational approaches to automatically generate mechanical designs that satisfy predefined specifications. Multimaterial mechanical design is formulated as a constrained non-convex multi-objective optimization problem, and various algorithms to solve these optimization problems are discussed. Topics include: review of the expert-driven design process; computational analysis tools based on mechanical simulation (finite element methods, mesh-free methods); topological optimization; compositional design; multi-objective optimization; evolutionary design; design for manufacturing with additive manufacturing (FDM, SLA, Inkjet). Students will use the methods presented to automatically design a mechanical part that

satisfies specifications.
Prerequisite of MCEN 3030 and/or MCEN 4043 for undergraduate students. Comparable prerequisite knowledge required for graduate students.

MCEN 5228: **Computational Fluid Dynamics** *(Offered by Prof. Debanjan Mukherjee)*
Computational fluid dynamics (CFD) techniques have become an integral component of modern engineering analysis of complex systems. This course will provide a broad introduction to the basic principles and applications of CFD. The core focus will be on computational solutions of flow and transport problems using the finite element method. Students will learn about the mathematical fundamentals of the finite element method, as well as techniques for geometry handling, mesh generation, assembly and solution of matrix systems derived from the governing equations, and post-processing of the resultant numerical solution. Students will get the chance to apply computational techniques to model and simulate realistic engineering fluid flow and transport problems. The course will culminate in a mini-conference/symposium style event where students will present their work to an audience comprising their peers, other students, and faculty.
Prerequisites of MCEN3021 and MCEN3030 for undergraduate students. Graduate students should have prior exposure to fluid mechanics, basic numerical methods, and computer programming. Strong interest in computer programming is beneficial.

MCEN 5228: **Materials & Devices in Medicine** *(Offered by Prof. Wei Tan)*
The main objective of this multidisciplinary course is to provide students with a broad survey of biomaterials and their use in medical devices for restoring or replacing the functions of injured, diseased, or aged human tissues and organs. The topics to be covered include: evolution in the medical device industry, a broad introduction to the materials used in medicine and their chemical, physical, and biological properties, discovery of medical problems, potential impacts of treatment innovations, existing devices and design considerations for several major physiological systems (cardiovascular, neuromuscular, skeletal, pulmonary, renal, dermal), materials interaction with the human body, basic mechanisms of wound healing, biocompatibility issues, testing methods and techniques in accordance with standards and relevant regulations, biofunctionalities required for specific applications, as well as state-of-the-art approaches for the development of new regenerative materials targeting cellular mechanisms.
Prerequisites of MCEN 2024 and MCEN 4/5117 for undergraduate students. Prerequisite of MCEN 4/5117 for graduate students.

MCEN 5228: **Biofluids at the Macro Scale** *(Offered by Prof. Debanjan Mukherjee)*
This course will provide a formal introduction to principles of biofluid mechanics at the macroscopic physiological scales. The average living human body is filled with fluids of over two dozen varieties âĂŞ each performing key functions essential for life and well-being. Developing a core understanding of macroscale physiological flows is essential for key advances in healthcare and medical technology. The course will explore the use of engineering principles of fluid flows and fluid-solid interactions to study physiological flow phenomena. This will include discussions of physiological processes in healthy and diseased states. The course will also explore the latest advances in medical imaging and image-based flow analysis. This will be a part of a two-course sequence (macroscale and microscale biofluids) - and students can take this course individually, or complete the sequence.
Recommended prerequisite of MCEN 3021 for undergraduate students. Comparable prerequisite knowledge required for graduate students.

MCEN 5228: **Regenerative Biology and Tissue Repair** *(Offered by Prof. Sarah Calve)*
This course covers the biological aspects behind the regeneration/repair and the utilization of engineering strategies to restore functionality of tissues compromised by injury and disease. The course is designed for graduate students and senior level undergraduates in any engineering or science discipline who have a desire to learn more about the fundamentals of biology that direct tissue formation. A range of tissues, including epidermal, neural, digestive, respiratory, digestive, musculoskeletal and cardiovascular, will be discussed based

on student interest. Key topics critical for understanding the biological underpinnings of tissue regeneration (e.g. immune response, cell-matrix interactions) will be emphasized.

MCEN 5228: **Mechanics of Cancer** *(Offered by Prof. Maureen Lynch)*
This course will cover the role of mechanics (emphasis on solid and fluid mechanics) in cancer and cancer-related processes. Course content includes experimental systems used to model and test these processes. No prior knowledge of biology is required to take this course. A limited overview of relevant biological processes will be covered as necessary.
Prerequisites of MCEN 2063 and MCEN 3021 (or equivalent) for undergraduate students. Comparable prerequisite knowledge required for graduate students. If you are uncertain whether you have the appropriate prerequisite knowledge, please contact maureen.lynch@colorado.edu.

MCEN 5228: **Thin Film Materials** *(Offered by Prof. Jianliang Xiao)*
This class is to give an introductory course to Thin Film Materials. The topics include: (1) Deposition and processing of thin film materials, (2) Theory of elastic beams, plates and 3D solids, (2) Film stress and substrate curvature, (3) Thin film on stiff substrates and applications to coatings, (4) Thin film on compliant substrates, and applications on flexible/stretchable electronics, (5) Modeling of adhesives, (6) Other applications.
Prerequisite of MCEN 2063 for undergraduate students. Comparable prerequisite knowledge required for graduate students.

MCEN 5228: **Mechanics of Snow** *(Offered by Prof. Franck Vernerey & Prof. Francois Barthelat)*
This course will introduce key concepts in the mechanics of snow over a wide range of time and length scales. Several concepts in solid mechanics will be covered in this process, including elasticity, viscoelasticity, micromechanics, failure criteria, damage mechanics, fracture mechanics, instabilities and cellular solids. Using these concepts we will describe the crystallographic structure of ice and snow, and how to connect this microstructure and its evolution over time to its mechanical properties. We will then discuss the concept of damage, where a weakening of the mechanical properties is induced by mechanical loading. We will also study how the weakening of snow around a defect can trigger a phenomenon called localization, that starts the fracture process. Criteria for snow fracture during avalanches will then be explored, both from a theoretical and experimental side, covering different trigger mechanisms at multiple length scales. We will then merge these concepts to better understand a number of phenomena in avalanche mechanics, such as the effects of localized load triggered by skiers and the topography of the mountain.
Prerequisite of MCEN 2063 for undergraduate students. Comparable prerequisite knowledge required for graduate students.

MCEN 5228: **Food Engineering** *(Offered by Prof. Carmen Pacheco-Borden)*
The objective of this course is for students to understand common unit operations and packaging materials used to manufacture foods and beverages with consistency, quality and safety. Food accounts for more than 12% of household expenditures, and the food industry is one of the largest retail industries in the U.S. Innovative and sustainable processes are needed to improve food quality and reduce energy, water, and other inputs in food processing. This course focuses on fundamental engineering principles and quantitative analyses of current and emergent techniques used in the processing of commercial foods and beverages. Topics include mass and energy balances, fluid mechanics, thermodynamics (e.g., water activity), heat and mass transport, thermal processes, acidified foods, frozen foods, refrigeration, drying, and packaging.

MCEN 5228: **Environmental Law for Engineers** *(Offered by Prof. Jana Milford)*
In Environmental Law for Scientists and Engineers, you will learn how environmental laws and regulations are developed and enforced by legislatures, state and federal agencies, and the courts. The course covers statutes and cases addressing air and water pollution, toxic substances, wastes, environmental assessment, and climate change. The course is designed for graduate students in engineering, environmental studies, and natural sciences. No legal background is required. The course is structured around reading and discussion, with students

required to brief cases and contribute to discussion of current issues. Written assignments include critical analysis of pending regulations and recent court opinions.

MCEN 5228: **Energy Materials Characterization** *(Offered by Prof. Chunmei Ban)*
This course introduces the fundamental theoretical framework for diffraction, spectroscopy and imaging methods used in the structural and morphological characterization of energy materials. The content is designed for graduate students who are interested in using morphological characterization techniques such as electron microscopy, structural characterization techniques such as X-ray diffraction and x-ray photoelectron spectroscopy, to investigate the materials structures and their relationship with properties and functionalities. Representative case studies in fields of energy storage or conversion applications will be used to help students learn newly evolved characterization techniques, and provide methodologies for design and optimization of materials in order to improve materials properties. This course will cover the characterization resources from National labs, and SEM training from CU Boulder COSINC-CHR. Three invited distinguished presentations on the applications of the SEM, TEM and XPS will be included here to help students better understand how to apply the characterization tools for materials development.

MCEN 5228: **Mechatronics 2** *(Offered by Prof. Derek Reamon)*
Continuation of MCEN 4115/5115, Mechatronics and Robotics. Focuses on design and construction of advanced microprocessor-controlled electro-mechanical systems. Lectures explore computer vision, machine learning, feedback control, multi-processor coordination and other advanced topics in mechatronics and robotics. Lab work reinforces lectures and allows hands-on experience with mechatronic design. Team-based design project integrates content into class-chosen design challenge.
Robots from Mechatronics 1 can be adapted or refined for use in the new design challenge. Mechatronics 1 and 2 do not have to be taken in the same year. Prerequisite of MCEN 4/ 5115, or permission of instructor.

MCEN 5228: **Nanomaterials** *(Offered by Prof. Xiaobo Yin)*
Understand fundamentals of the materials sciences and solid state physics that are uniquely associated with nanostructures and nanomaterials. To understand how the properties of a nanomaterial, such as mechanic, electronic, optical, and magnetic properties, can be affected and even substantially tailored by the size, geometry, composition and the structure of the nanomaterial. Understand the fundamental concepts in the design, manufacturing, characterization and application of functional nano-materials/structures. Develop the skill to be conversant in the multiple disciplines that involve nanomaterials and be aware of the social, ethical and environmental impacts resulting from the involved nanotechnology.
Prerequisite: MCEN2024.

MCEN 5228: **PBL in Rural Schools** *(Offered by Prof. Daniel Knight)*
Focuses on the use of low cost air quality monitoring tools, dubbed Pods, to implement PBL curriculum in high school environmental science classes in rural communities in Colorado. Each student will be paired with a high school class and will serve as curriculum and technology advisors as well as science experts. During the fall semester, students will be trained to effectively work in those roles and will also travel to their schools to be introduced. During the spring semester, students will support high school teachers in implementing an existing PBL air quality curriculum with the Pods. This will include monthly visits to schools in the spring and reporting back to the class.
This is a full-year course. Interested students should contact daniel.knight@colorado.edu to request enrollment access.

MCEN 6228: **Wetting, Adhesion & Friction** *(Offered by Prof. Rong Long & Prof. Yifu Ding)*
This course aims to discuss fundamentals of liquid wetting of a solid surface, adhesion and friction between two contacting surfaces. These interfacial interactions are critical across a broad spectrum of applications from traditional field of rubber tire to emerging areas of designing anti-icing surfaces. The course will examine theories and findings for both conventional materials such as metal and ceramics and more complex soft

materials.

Oral Preliminary Exams

E.1 Oral Preliminary Exam Guidelines

The oral preliminary exams are typically taken by PhD students at the very beginning of their second year in the PhD program. These exams are focused on assessing understanding of fundamental knowledge and are not research focused. The exams are oral in order to prepare students for comprehensive exams, PhD defenses, conference presentations, job talks, TA duties, and teaching, all of which require oral communication.

The primary purpose of these exams is educational, and all feedback provided to students is intended to be constructive. Consistent with the educational mission of these exams, the most common outcome for students who struggle on the exams is a conditional pass, where the condition placed on the students is intended to address a perceived area of weakness that requires further attention and improvement. There is also no set pass (or fail) rate for these exams; all students can pass, or all can fail.

All exams take place the first week of the fall semester, with all results and feedback reported to students by the end of this week.

E.1.1 Oral Preliminary Exam Topics

All PhD students are required to take two from a list of seven topic exams. Corresponding preparatory courses for each topic are listed below:

- **Biomedical, Biomaterials & Biomechanics (BioM^3)** (offered for students enrolled prior to Fall 2022): MCEN 5117 Anatomy & Physiology for Engineers
- **Controls**: MCEN 5228 Linear Systems
- **Fluid Dynamics**: MCEN 5021 Introduction to Fluid Dynamics
- **Heat Transfer**: MCEN 5042 Heat Transfer
- **Materials**: MCEN 5024 Materials Chemistry and Structures
- **Mechanics**: MCEN 5023 Solid Mechanics
- **Thermodynamics**: MCEN 5022 Classical Thermodynamics

Although the preparatory courses are strongly recommended prior to taking the oral preliminary exam, they are not required.

E.1.2 Format

Each exam is oral and is delivered by a committee of two faculty. The committee cannot include the student faculty advisor, and advisors are not consulted when making final decisions on exams.

Exams are printed out (without solutions) and given to students 10 min prior to the start of the question and answer period so that they can read the entire set of questions in advance and begin to think about their problem-solving approach; students should sign the honor code at the top of each exam and return it at the end. Each exam consists of the following components:

- 10 min exam preview period;
- 30 min question and answer period;
- 5 min closed-door faculty discussion to assess student;
- 5 min feedback to students regarding the correct solutions and approaches (**not to include** evaluation of the students' individual performance or pass/fail/conditional pass decision).

Students will be notified via email by the end of the first week of classes with the final decision (pass/fail/conditional pass). Those receiving conditional or failing evaluations will be required to meet with the graduate committee chair or topical exam lead to discuss the results; those passing will be given the option to meet with the topical exam lead for feedback.

E.1.3 Questions

The oral preliminary exams are intended as a test of fundamental knowledge in a particular subject area; as such, research questions and presentations are not part of these exams. Due to the oral format, questions are focused on testing conceptual understanding, critical thinking skills, and intuition.

Each student taking the oral prelim in a particular subject area is, to the greatest extent possible, asked the same questions at the same difficulty level. Exams are written such that they can be completed in the allotted time, and the time per question is listed on the exam to ensure that faculty examiners cover sufficient material on the exam to evaluate each student.

Topics on the exams are only those listed on the concept inventories provided in Section E.2.

A collection of oral prelim exams from previous years is available here.

E.1.4 Preparation

Concept inventories are provided for each topic exam in Section E.2, and a Google drive folder available here contains old exams and other information related to the oral preliminary exams.

Faculty-led information sessions are held at the beginning of the summer to outline each exam; these sessions are recorded and uploaded to Google drive. These sessions typically include the faculty lead solving an example problem (e.g., from a previous year) to demonstrate a successful preliminary exam response for the students. In some cases, additional faculty-led info sessions and office hours may be held for the students later in the summer.

Peer-led oral exam practice efforts are also organized by the lead graduate teaching fellow to facilitate growth with oral defense. These practices include study groups and mock exams; information on how to become involved in these peer-led efforts is provided by the lead graduate teaching fellow at the beginning of each summer.

E.1.5 Evaluation

As much as possible, faculty are encourage to adhere to Bloom's taxonomy to assess learning objectives and evaluate students taking each exam. Although specific adaptation to each exam is expected, we encourage faculty to assess students based on their ability to:

1. **Remember:** Recall facts and basic concepts;
2. **Understand:** Explain ideas and concepts;
3. **Apply:** Use information to solve problems;
4. **Analyze:** Draw connections among ideas;
5. **Evaluate:** Support, defend, and critique a solution;

6. **Create:** Produce new original ideas.

These skills are ordered from lower- (i.e., remembering) to higher-order (i.e., creating) thinking skills. In order to pass the oral preliminary exams, a student is not necessarily required to demonstrate aptitude in all of these skills (for example, a student may run out of time on an exam before demonstrating an ability to "create"). However, we do ask faculty examiners to keep these skills in mind when formulating exams and evaluating students.

Helpful examples of question verbs used to evaluate each of these skills are available on this website. Example verbs and expectations are summarized below:

1. **Remember:** List, recite, outline, define, name, match, quote, recall, identify, label, recognize.
   Example: The student can recite Newton's three laws of motion.
2. **Understand:** Describe, explain, paraphrase, restate, give original examples of, summarize, contrast, interpret, discuss.
   Example: The student can describe Newton's three laws of motion in their own words.
3. **Apply:** Calculate, predict, apply, solve, illustrate, use, demonstrate, determine, model, perform, present.
   Example: The student can calculate the kinetic energy of a projectile.
4. **Analyze:** Classify, break down, categorize, analyze, diagram, illustrate, criticize, simplify, associate.
   Example: The student can differentiate between potential and kinetic energy.
5. **Evaluate:** Choose, support, relate, determine, defend, judge, grade, compare, contrast, argue, justify, support, convince, select, evaluate.
   Example: The student can determine whether using conservation of energy or conservation of momentum would be more appropriate for solving a dynamics problem.
6. **Create:** Design, formulate, build, invent, create, compose, generate, derive, modify, develop.
   Example: The student can design an original homework problem dealing with the principle of conservation of energy.

Examiners take 5 minutes at the end of each exam to determine which objectives were met by the student, with justifications and explanations provided. Examiners may choose to add quantitative metrics [e.g., from 1 (poor) to 5 (excellent)] to aid in the assessment of these objectives, but the feedback given to students is qualitative in nature.

E.1.6 Outcomes

To provide time to identify any potential biases or problems with each exam, final decisions are not delivered to students immediately after each exam. Once all exams are completed, all committee members for each exam will meet to discuss scores and determine final decisions; the advisor is not part of the discussion on whether their student passes/fails.

Final decisions are communicated to students by email at the end of the first week of classes, after all exams have been completed. For each exam taken, students receive their final decision (i.e., pass, fail, or conditional pass) and a written explanation of the decision. If a student receives a conditional pass, the condition placed on the student is also described. All students who receive a conditional pass or failing grade on any exam are required to meet with either the graduate program chair or the lead faculty for that exam. Students who pass an exam are not required to attend any additional meetings, although they are given the option to meet with the graduate program chair or lead faculty if desired.

The most common outcome for students who struggle on an oral preliminary exam is a conditional pass. A conditional pass can take many forms, including taking an additional course, guest lecturing for a course, or completing an additional report or assignment. In general, the condition imposed on the student is intended to address areas identified as needing improvement during the oral exam. Once the condition is satisfied, the student is considered to have completed their oral preliminary exam(s).

Students failing one or both of their oral preliminary exams will not necessarily be removed from the PhD program. Many such students will be given the opportunity to retake the exam the following year, pending a discussion with the student's advisor.

E.2 Oral Preliminary Exam Concept Inventories

Concept inventories are provided in this appendix for each of the oral preliminary exam topics: BioM^3, Controls, Fluid Dynamics, Heat Transfer, Materials, Mechanics, and Thermodynamics. Additional details on the oral preliminary exam structure and expecations are provided in Section 4.4.6, and PhD students must choose and pass the oral preliminary for two of these seven fundamental topics.

E.2.1 Biomedical, Biomaterials, and Biomechanics (BioM^3)

Fall 2022 Faculty Lead: Wei Tan (wei.tan-1@colorado.edu)

Summary: Students who plan to take the BioM^3 preliminary exam in the Department of Mechanical Engineering will be required to satisfy several requirements. Students will need to enroll in *Anatomy and Physiology for Engineers*, an annual course that addresses fundamental topics at the interface of engineering and biology. Qualified students will be permitted to petition out of this course, on a case-by-case basis. In any case, students will be responsible for information covered in Units 1-3 of the course textbook, listed below.

Text: *Quantitative Human Physiology: An Introduction*, by Joseph Feher

BioM^3 Topics (Following the Text):

- *Unit 1 Physical and Chemical Foundations of Physiology*
  Chapter 1.1 – The Core Principles of Physiology
  Chapter 1.2 – Physical Foundations of Physiology I: Pressure-Driven Flow
  Chapter 1.3 – Physical Foundations of Physiology II: Electrical Force, Potential, Capacitance, and Current
  Chapter 1.4 – Chemical Foundations of Physiology I: Chemical Energy and Intermolecular Forces
  Chapter 1.5 – Chemical Foundations of Physiology II: Concentration and Kinetics
  Chapter 1.6 – Diffusion
  Chapter 1.7 – Electrochemical Potential and Free Energy
- *Unit 2 Membranes, Transport, and Metabolism*
  Chapter 2.1 – Cell Structure
  Chapter 2.2 – DNA and Protein Synthesis
  Chapter 2.3 – Protein Structure
  Chapter 2.4 – Biological Membranes
  Chapter 2.5 – Passive Transport and Facilitated Diffusion
  Chapter 2.6 – Active Transport: Pumps and Exchangers
  Chapter 2.7 – Osmosis and Osmotic Pressure
  Chapter 2.8 – Cell Signaling
- *Unit 3 Physiology of Excitable Cells*
  Chapter 3.1 – The Origin of the Resting Membrane Potential
  Chapter 3.2 – The Action Potential
  Chapter 3.3 – Propagation of the Action Potential
  Chapter 3.4 – Skeletal Muscle Mechanics
  Chapter 3.5 – Contractile Mechanisms in Skeletal Muscle
  Chapter 3.6 – The Neuromuscular Junction and Excitation-Contraction Coupling
  Chapter 3.7 – Muscle Energetics, Fatigue, and Training
  Chapter 3.8 – Smooth Muscle
- *Unit 5 The Cardiovascular System*
  Chapter 5.1 - Overview of the Cardiovascular System and the Blood

Chapter 5.4 - The Heart as a Pump
Chapter 5.5 - The Cardiac Action Potential
Chapter 5.6 - The Electrocardiogram
Chapter 5.7 - The Cellular Basis of Cardiac Contractility
Chapter 5.8 - The Cardiac Function Curve
Chapter 5.9 - Vascular Function: Hemodynamics
Chapter 5.10 - The Microcirculation and Solute Exchange

E.2.2 Controls

Fall 2022 Faculty Lead: Shalom Ruben (shalom@colorado.edu)

Relevant MCEN Courses:

- MCEN 4043 System Dynamics (prerequisite to Feedback Control)
- MCEN 4228/5228 Feedback Control (prerequisite to Linear Control Systems)
- MCEN 5228 Linear Control Systems

Classical Control:

- Laplace transforms
- First and second order system response
- Impulse response
- Sinusoidal response, Bode diagrams
- Root locus
- Nyquist criterion and analysis
- Gain and phase margins
- PI/lag control, PD/lead control, PID control
- Translation of closed loop performance requirements into open loop constraints
- Loopshaping design

Linear Control Systems (State Space):

- Theory of vector spaces; bases, dimension, linear independence, norms, inner products, orthogonality and projections, Gram-Schmidt
- Theory and solution of static linear systems $Ax = y$
- Decomposition of linear transformations using eigenspaces
- Matrix exponentials; Jordan form; modal form
- Solutions of homogeneous linear systems using linear operator decompositions
- Solutions of forced linear systems
- Stability of state space systems; relation to eigenvalues
- Controllability, observability, stabilizability and detectability; associated tests
- State feedback control; pole placement
- Observer design to reconstruct internal states

E.2.3 Fluid Dynamics

Fall 2022 Faculty Lead: Xiaoyun Ding (xiaoyun.ding@colorado.edu)

For any problem, you should be able to:

1. Identify the physical processes and fluid properties
2. Formulate mathematical models
3. Select methods of analysis and computation including solution of basic diff. equations.
4. Develop first-cut solutions and interpret them in physical terms

5. Explain what you have learned in the context of an oral exam

With a focus on the following:

1. Basic Balance Laws – mass, momentum, energy
2. Kinematics
3. Similarity
4. Vorticity Dynamics
5. Viscous Flows
6. Boundary Layers

Also, familiarize yourself with the following:

1. Physical properties of gases and liquids (for example: viscosity, surface tension, vapor pressure)
2. Kinematics of flow fields including flow acceleration, streamline, streak-line, and particle path concepts, Reynolds transport equation;
3. Conservation laws (mass, momentum and energy) and the governing equations of general fluid flows (integral and differential forms);
4. Relation between stress and deformation-rate tensors;
5. Internal and kinetic energy equations;
6. Viscous dissipation;
7. Vorticity equations;
8. Dimensionless form of the equations and Reynolds number;
9. Classification of flow regimes;
10. Exact solutions and rational approximations for viscous flows (e.g., Couette, Poiseuille, etc.);
11. Similarity solutions;
12. Boundary layer, displacement, and momentum thicknesses;
13. Blasius solutions;
14. Flow separation;
15. Cavitation;
16. Flow around cylinders, spheres, and other immersed bodies;
17. Transition to turbulence;
18. Structure of turbulent flows;
19. Laminar vs. turbulent boundary layers.

You are allowed to bring with you to the exam one single page (8.5 × 11 in) double-sided or two pages (8 × 11 in) single-sided handwritten equation/concept sheet. There should NOT be example problems written on the sheet.

E.2.4 Heat Transfer

Fall 2022 Faculty Lead: Longji Cui (longji.cui@colorado.edu)

Relevant Courses:

- MCEN 3022 Heat Transfer (Undergraduate level)
- MCEN 5042 Heat Transfer (Graduate level)

The exam will be primarily based on the course contents of MCEN 3022 and MCEN 5042. A student might do reasonably well if they have a true mastery of MCEN 3022. However, attending MCEN 5042 is strongly encouraged. Some challenging problems that cover a wide but integrated spectrum of fluids/thermal sciences such as fluid mechanics, thermodynamics, and heat transfer are expected.

Basic Coverage of MCEN 3022:
The fundamental equations that govern heat transfer are developed and applied to various practical cases of

interest, including aerospace applications, high temperature materials, thermal management of electronics, power generation, buildings and HVAC systems, and manufacturing applications. Solution techniques for systems of differential equations that describe heat transfer processes are reviewed and/or developed. Transient as well as steady state conduction in various geometries is studied. Correlations are developed for convective heat transfer in tubes and ducts as well as over external surfaces. Both natural and forced convection are studied. Radiative heat transfer between various surfaces of different temperatures and surface properties is emphasized. Heat exchanger theory will also be covered.

1. Conduction:

- Calculate heat transfer rates for steady unidirectional conduction in thin wall and thin shell configurations.
- Use analytical methods to calculate heat transfer rates for steady multidirectional conduction in simple configurations.
- Calculate temperature profiles and heat transfer rates for multi-directional steady-state conduction using analytical methods for simple geometries.
- Set up and solve discrete control volume/finite difference formulations for numerical solution of steady state conduction problems.
- Analyze problems involving transient conduction using approximate methods.
- Set up and solve finite different equations for transient conduction problems.
- Select appropriate solution methods for transient conduction problems.

2. Convection:

- Define and evaluate the key dimensionless parameters that characterize flow fields and convective heat transfer in external configurations.
- Use similarity solutions and empirical correlations to evaluate heat transfer coefficients or heat transfer rates for external forced convection in laminar and turbulent flow regimes.
- Use similarity solutions and empirical correlations to evaluate heat transfer coefficients or heat transfer rates for internal forced convection in laminar and turbulent flow regimes.
- Qualitatively describe flow and temperature fields in external boundary layers and within pipes and ducts.
- Qualitatively describe the driving forces that govern natural convection.
- Define and evaluate the dimensionless parameters that characterize natural convection.
- Use empirical correlations to evaluate heat transfer rates for natural convection in external and internal flow configurations.

3. Radiation:

- Analyze radiative heat transfer between black or diffuse gray surfaces, using geometric shape factors together with fundamental descriptions of thermal radiation.

4. Contemporary Issues in Heat Transfer

- Apply knowledge of heat transfer to current issues, including aerospace applications, high temperature materials, electronic systems, combustion systems, power generation including solar energy, machinery and manufacturing applications.
- Apply fundamentals of conduction, convection and radiation to heat exchanger analysis and design. Identify heat transfer mechanisms, formulate energy balance equations, and choose appropriate methods for evaluating the conduction, convection or radiation terms in the energy balance equation.

In covering the above topics, there should be three overriding objectives:

(a) The student should appreciate the physical origins of the various transport mechanisms. Moreover, when

confronted with a particular problem, (s)he should be able to identify the relevant transport processes.

(b) The student should be able to perform engineering calculations for problems involving heat transfer. (S)he should know when, and of what nature, simplifying approximations may be made. (S)he should also be able to perform the kinds of calculations which lead to a rational design and/or an improved understanding of the performance of heat exchange systems.

(c) A final, yet equally important objective, is to develop a positive attitude towards the subject of heat transfer. It is incumbent upon the instructor to reveal the vital role which such processes play in the natural and industrial worlds and to thereby transmit a sense of excitement for the subject.

Basic Coverage of MCEN 5042:
Topics to be covered include: conservation laws, some heat conduction, laminar and turbulent convection (forced and natural), heat and mass transfer including phase change (boiling, evaporation, and condensation), and basic thermal radiation. Students need to learn and show the fundamentals skills on how to model thermal transport processes in typical engineering systems. Problems and examples will include theory and applications drawn from a spectrum of engineering systems, such as manufacturing and machinery, power systems, building systems, solar-thermal utilization, electronics cooling, and even personal thermal management.

E.2.5 Materials

Fall 2022 Faculty Lead: Yifu Ding (yifu.ding@colorado.edu)

Material Structures, Physics, and Chemistry:

1. Atomic, Molecule, and Crystal Structures and Properties
2. Bonding and Inter-molecular Interactions
3. Band Theory of Solids (metals, semiconductors, and non-metals)
4. Alloys and Ceramics
5. Defects
6. Surfaces and Interfaces
7. Materials Characterizations (Structures and Fundamental Properties)

Materials Thermodynamics and Kinetics:

1. Basic Laws of Thermodynamics
2. Entropy
3. Thermodynamic Properties of Pure Substances and Mixtures
4. Phase Equilibrium and Transformations
5. Basic Phase Diagram and Related Physical and Mechanical Properties

Materials Mechanics:

1. Mechanical Behavior of Crystalline and Non-crystalline Materials
2. Basic Solid Mechanics Concepts, Formulations, and Problem Solving (Tension, Shear and Torsion; Transformation of Strain and Stress Components, Generalized Hooke's Law, and General Formulation Linear Elasticity Problems)
3. Stress Concentration and Materials Failures
4. Stress and Strain Sensing Principles and Sensors

Polymer Materials:

1. Polymer Chain Formation, Configuration, and Basic Structures
2. Crystalline and Amorphous States of Polymers, and Solution and Phase Behavior of Polymers
3. Rubber and Viscoelastic Mechanical Properties of Polymers

Recommended Reference Books:

- W. D. Callister, Jr. and D. G. Rethwisch, *Fundamentals of Materials Science and Engineering: An Integrated Approach, 4th Ed.*
- A.C. Ugural, S.K. Fenster, *Advanced mechanics of materials and applied elasticity, 5th ed.*, Prentice Hall.

E.2.6 Mechanics

Fall 2022 Faculty Lead: Rong Long (rong.long@colorado.edu)

Mechanics of Materials:

1. Tension, simple shear and torsion
2. Multi-axial strain and stress components
3. Principle stress/strain and directions
4. Transformation of strain and stress components
5. Compatibility equations for strain
6. Generalized Hooke's law
7. General formulation of linear elasticity problems
8. Plane strain & plane stress conditions
9. Thermal stress
10. Stress concentration
11. Energy method (Castigliano's theorem)
12. Stability of columns and buckling

Continuum Mechanics:

1. Kinematics of continuum bodies
2. Material and spatial derivative
3. Deformation gradient and strain tensors
4. Stress tensors (Cauchy, first and second Piola-Kirchhoff)
5. Balance principles (mass, momentum and energy)
6. Entropy inequality

Mechanics of Beams and Plates:

1. Bending moment, shear force and distributed load
2. Deflection of beams
3. Composite beams
4. Pure bending of beams with assymmetrical cross section
5. Kirchhoff plate theory
6. Bending and stretching (membrane theory or plate theory)

Inelasticity:

1. Plastic deformation
2. Yielding and yield criteria
3. Strain hardening
4. Plastic flow law
5. Viscoelasticity (Maxwell model, Kelvin-Voigt model, Standard linear solid model)
6. Creep and stress relaxation
7. Relaxation modulus and Prony series
8. Storage and loss modulus

Recommended Reference Books:

- A.C. Ugural, S.K. Fenster, *Advanced mechanics of materials and applied elasticity, 5th ed.*, Prentice Hall.
- A.F. Bower, *Applied Mechanics of Solids*, CRC Press.

E.2.7 Thermodynamics

Fall 2022 Faculty Lead: Jeremy Koch (jeremy.koch@colorado.edu)

The prelim will cover topics from standard undergraduate and graduate classical thermodynamics courses.

When preparing for the prelim, focus less on memorizing equations and more on starting from first principles and building up to a problem solution. Be sure to practice working out problems on a board in front of others.

Prelim concepts follow *Thermodynamics: An Engineering Approach* by Cengel and Boles:

- Properties of pure substances
- Closed and open system analysis (control mass and control volume)
- 1st law of Thermodynamics
- 2nd law of Thermodynamics
- Entropy
- Cycles: Gas power, vapor & combined power, refrigeration (incl. thermodynamic diagrams)
- Thermodynamic property relations, gas mixtures, gas-vapor mixtures (psychrometrics)
- Chemical reactions
- Chemical and phase equilibrium

For every problem you should be able to:

- Gather and collate given information: what is known, what you are trying to find, and what assumptions you will need to make
- Draw appropriate system diagrams
- Draw appropriate thermodynamic diagrams
- Articulate your solution approach step-by-step, using appropriate technical language and demonstrating proficiency with the thermodynamic concepts

E.3 Studying for the Prelims by John Daily

These notes offer my personal guide to the Preliminary Examinations. They are based on almost forty years of experience, starting with my own journey through the Ph.D. First I'll make some observations about the nature of the Ph.D. and the purpose of the exams and what we the faculty are seeking. I'll then offer some specific advice on preparing for them.

The Doctor of Philosophy Degree (Ph.D.) is the most advanced degree offered by research universities worldwide. It is designed to prepare students for careers in education, research or industry at the highest levels. It is a demanding program that offers the opportunity to excel in a particular technical field, while becoming highly effective in planning, oral and written communication, and other management skills that will have a long lasting impact on your career. Our goal is to assist you in becoming an effective, self-motivated researcher with a broad grasp of your discipline and the ability to relate what you do to the larger world around you.

The purpose of the preliminary examination is to assess the probability of your success in the program, and, more importantly, it is an opportunity for you build a strong base of integrated disciplinary knowledge that will serve you well for the rest of your career. It is not possible to rush preparation for the exams. To turn in a credible performance, you must be prepared at a very high level. You will be asked to solve and discuss problems from a fairly mature perspective. That means being prepared to cross boundaries between subject areas, and see relationships not necessarily explored deeply in the undergraduate curriculum. Much will be asked in an oral environment, one that most of you are relatively unfamiliar with. And you will be feeling a great deal of pressure.

The Fundamental Knowledge Examination

There are three major elements to the Fundamental Knowledge exams:

1. Basic Disciplinary Knowledge

It is important that you have a global picture of the basic disciplinary fields you are to be working in. Thus, you must codify your knowledge in each of the areas being tested. This is best done by systematically developing your own set of notes summarizing the major concepts, important numbers, etc.

2. Basic Problem Solving

You must be able to rapidly solve a variety of basic problems of the type you worked in your undergraduate courses. You must be able to systematically formulate the problem in a way that leads clearly to a solution method, carry out the solution, and understand the significance of your findings. The best sources for such problems are textbooks of the type recommended for the areas. You must systematically solve large numbers of problems to become truly adept.

3. Compound Problem Solving

In the exams, you will be asked to solve problems that require more than one discipline. For example, you may have to solve a fluid mechanics problem as part of a heat transfer question. The question might involve needing to identify a particular flow regime as being critical to the heat transfer problem, say a boundary layer. You would then need to approximate the boundary conditions, and solve for the temperature profile. You can best prepare for such questions by selecting real world applications and asking yourself how you would attack analyzing the system. For example, what would be required to predict the real efficiency of an automotive turbocharger? Calculating the ideal efficiency is a basic problem solving skill. Dealing with heat transfer and friction losses is a compound problem solving skill.

Research Evaluation Examination

The Research Evaluation Examination requires you to become an expert in a single topic, and demonstrate that you have the ability to conceptualize the problem, propose a hypothesis or research scenario, and make progress toward a solution. Your oral presentation should include the following components:

1. A clear statement of your research problem.
2. A discussion of the research history for this problem, citing appropriate literature.
3. A description of the experimental and/or numerical/computational methods needed or used to address the research problem. Include statistical and/or uncertainty analysis where appropriate.
4. A discussion of your findings to date.
5. A summary and statement of your conclusions, including recommendations for future direction the research might take.

During and following your presentation, you will be asked a range of questions to assess how well you understand each element and the maturing of your approach.

Preparing

Clearly, being successful will require systematic preparation. The following suggestions have been proven over time, and I strongly urge you to make a study schedule similar to this and plan accordingly. The plan is design to give you ample opportunity to study for the exams, while allowing you to continue taking classes, working on research projects and having some semblance of a normal life.

First form a study group with at least one, but preferably two or three, other students who will be taking the same exams. If English is not your native language, avoid forming a group of other non-English speakers. You will be working with this group to develop your oral problem solving skills and to practice your research

presentations.

Next, determine how many basic disciplinary areas you must prepare for. Set aside a period so that you have two weeks for each area (this might vary depending on the depth and complexity of the area), starting so that it ends three weeks before the exams. For this period set a regular meeting time for the group. The lunch hour is a good time. You should meet once every week for each student in the group. Thus, two students meet twice a week, three students meet three times a week, etc. Meet in a place with a blackboard. It will be tempting to shortcut this time, but it is critical to developing good oral skills. Assign each two-week period to a disciplinary area. You should order them in a logical way, starting with the most basic and working up. Once your overall schedule is set, set aside two contiguous hours every weekday or evening for individual study. This is the time you will use to outline the area, and do problems on paper.

At the beginning of each two-week period, discuss with your group the nature of the area, what you think the scope of the exams might be, and what sources you will use for problems. Assign each group member the task of providing problems to have the other students practice in the oral setting. Each student should spend at least an hour a week answering questions at the board. Start you individual study each two-week period by outlining the area, then filling in your notes. One suggestion is to spend the first hour of each two-hour period working on your notes. Then do problems during the second hour. By the end of the overall period, you should have developed a very strong sense for each area, solved a large number of problems, and begun to feel much more comfortable in the oral setting.

You now have two weeks left. During the first of these, prepare short one-page summaries from the area notes you prepared earlier. This serves to consolidate your memory of each area and forces you to prioritize what information you think is most important.

During the second week, take a break. Go to the movies, get plenty of exercise, and eat well. Splurge on a nice dinner out. Sleep in. You want to enter the exams well rested. Don't worry, your mind will still be thinking about the exams, and you can put some (but not too much) time into checking up on some of those difficult questions you never really understood.

You will notice that I am NOT asking you to stay up all night, study weekends, give up your other course work, give up research, or stop exercising and eating properly. I am asking you to plan ahead, be systematic, and spread out studying over a sufficiently long period so that you won't have to do those things mentioned in the previous sentence. In fact, the ability to make and carry out such plans is the hallmark of a successful Ph.D. and a person with a successful career. Learn to do it, and you will be rewarded many times over.

Research Preliminary Exams

F

F.1 Research Preliminary Exam Guidelines

The intent of the research preliminary exam is to evaluate the potential of a PhD student to perform doctoral level research. The exam is focused primarily on the PhD student's plan for future research, but may also include preliminary research results. The research preliminary exam should be completed within 1 year of passing the oral preliminary exam, but no later than fall semester of the 3rd year.

There are both written and oral components to the research preliminary exam, as outlined in the following:

- **Written research proposal:** Students should prepare a report, with figures and references, describing their proposed PhD research. The report should consist of the following elements:
  1. *Cover page (1 page):* High-level information on the proposed project, including the project title, names of all project participants and their affiliations (including the student, advisor, and collaborators), and the project abstract (300 words max).
  2. *Project narrative (maximum 4 pages):* A description of the proposed research, including the following elements:
     (a) Background and review of prior literature (1 page);
     (b) Problem definition and project objectives (less than 0.5 page);
     (c) Research plan including timeline (1-2 pages);
     (d) Preliminary (if available) and expected research results (0.5 page);
     (e) Impact of proposed research (less than 0.5 page).
  3. *References*

  The written research proposal should be prepared using Microsoft Word, LaTeX, or other word processor and should be formatted with 11pt Arial or Times New Roman font, 1 in margins, single spacing, and letter paper (8.5 in×11 in). The report should be well written with proper citations of prior work and minimal grammatical and typographical mistakes. All reports will be checked for plagiarism.
- **Oral presentation:** In addition to the written proposal, PhD students taking the research preliminary exam should prepare and deliver a 30 minute oral presentation, with slides, describing the proposed research and covering all aspects of the written report. The student and committee will then hold a closed-door question and answer period (roughly 30 minutes) immediately after the presentation. The committee will ask challenging questions of the student to test the bounds of the student's knowledge and research potential.

Both the written report and oral presentation should be understandable to committee members who have a great deal of technical experience and knowledge, but who are not necessarily experts in the exact area of the proposed research.

Students are encouraged to provide their written report to their advisors for feedback prior to sending the report to the preliminary exam committee. Students are also encouraged to practice their oral presentation with their advisor and lab-mates.

F.1.1 Personnel

Students are responsible for selecting and forming their own preliminary exam committees; students are strongly encouraged to discuss potential committee members with their research advisors. The following committee guidelines must be followed:

- 3 Department-approved committee members are required (including Advisor). 2 committee members must be mechanical engineering faculty.
- Additional committee members are allowed if desired; these additional members can include faculty outside of mechanical engineering and/or CU.
- No guests are permitted during the preliminary exam beyond the committee, including other faculty, students, family, etc.

Although present during the exam, PhD advisors are encouraged to not intervene or assist students during the exam, except in cases where clarifications are needed. The intent is to evaluate the student research progress, without assistance.

F.1.2 Procedure

At least one week prior to the exam, students must send their written research proposal as a PDF document to all committee members, as well as to megrad@colorado.edu. This email should also include the names of all committee members for approval by the graduate program.

The student is responsible for scheduling the time and location of the preliminary exam presentation; students must organize the exam and coordinate schedules with the committee. Both in-person and virtual (via Zoom) exam presentations are permitted. The department does not schedule these exams.

Students taking the exam in-person should bring the research prelim form with them to the exam; this form is available here. Alternatively, a copy of this form can be sent to the committee via Docusign by emailing megrad@colorado.edu.

F.1.3 Evaluation

The written research proposal and oral presentation will each be evaluated according to the following criteria:

1. **Literature and Previous Work:** Demonstrates sound knowledge of literature in the area, and of prior work on the specific research problem.
2. **Problem Definition:** States the research problem and objectives clearly, providing motivation for undertaking the research.
3. **Research Plan:** Provides a sound plan for applying state-of-the-field research methods/tools to solving the defined problem and shows a good understanding of how to use methods/tools effectively.
4. **Preliminary and Expected Results:** Provides a sound plan for analyzing and interpreting research results/data.
5. **Impact of Proposed Research:** Demonstrates the potential value of solution to the research problem in advancing knowledge within the area of study. Also demonstrates awareness of broader implications of the proposed research. Broader implications may include social, economic, technical, ethical, business, etc. aspects.
6. **Quality of Written/Oral Communication:** Communicates research proposal clearly and professionally in both written and oral forms.

7. **Critical Thinking:** Demonstrates capability for independent research in the area of study, preparedness in core disciplines relevant to research, and ability to complete the proposed research.

In each of these categories, students will be given a rating of:

- Needs Significant Improvement;
- Needs Improvement;
- Acceptable;
- Very Good;
- Excellent.

Students must receive a rating of "Acceptable" or above for each of the seven evaluation criteria. A rating of "Needs Improvement" or "Needs Significant Improvement" in any category does not necessarily mean the student has failed the exam; instead, the committee may choose to pass the student with conditions, where the conditions are intended to address the criteria above.

Students will receive their evaluations and exam results immediately following the closed-door question and answer period during the oral preliminary exam.

F.1.4 Outcomes

Students can pass, fail, or conditionally pass the exam. A failing grade does not necessarily mean the student is out of the PhD degree program and is often encouraged to retake the exam. The conditions placed on conditional passes should be designed to address the perceived weakness of the student (e.g., guest lecturing in a class, writing a brief report, meeting again with a committee member, etc.).

Students who fail the research preliminary exam must retake the exam and pass within 1 year of the first exam; failure to pass this exam may result in removal from the PhD program. Students who conditionally pass the research preliminary exam will typically have less than a year to complete their condition; again, failure to satisfy the condition(s) may result in removal from the PhD program.

The exam is considered complete when all faculty have signed off on the Research Preliminary Exam form.

G Resources for Teaching Assistants

G.1 Center for Teaching and Learning

The Center for Teaching and Learning (previously known as the Graduate Teaching Program) is a graduate and professional student development program that strives to encourage graduate students to embrace teaching as an intellectual and inclusive act and to pursue their personal and professional development through participation in the program. The Center for Teaching and Learning (CTL) provides workshops that focus on pedagogical techniques and professional development. In addition to workshops offered throughout the year, the CTL holds two training events each year, the Fall Intensive and Spring Conference. These training events are open to all graduate students.

To encourage graduate students to focus on gaining teaching skills, the CTL also offers two certificates and in college teaching and future faculty development. The two certificates include, the Certificate in College Teaching (CCT) and the Future Faculty Development Certificate (FFD). The CCT helps graduate teachers develop a confident classroom presence, good interactional skills, and a firm foundation in college teaching. Graduate students must teach for two semesters to pursue this certificate.The FFD offers graduate students the opportunity to pursue a project on teaching at the college level under the guidance of a faculty mentor. Graduate students are not required to teach to pursue this certificate. While the Pursuing Excellence in College Teaching Credential (CTC) allows graduate students whose programs do not offer opportunities for classroom teaching, or for those who are not able to complete the Certificate in College Teaching (CCT). Links to the requirements for each certificate/credential are listed below.

- Certificate in College Teaching (CCT)
- Future Faculty Development Certificate (FFD)
- College Teaching Credential (CTC)

G.2 Lead Graduate Student

The Lead Graduate Student of the Mechanical Engineering department works closely with both the department and the CTL to advance teaching and professional development in the department. Through this position, the Lead Graduate Student will receive training in academic management, academic leadership, college pedagogy, collegial teamwork and project management.

Responsibilities of the Lead Graduate Student are listed below:

- Develop and implement an original project that contributes to the improvement of teaching and/or professional development in the Mechanical Engineering Department

- Organize orientation for the incoming 1st year PhD students
- Participate and help to organize the College of Engineering and Applied Science orientation
- Meet with 1st year PhD students individually during the Fall and Spring semester for check-in meetings
- Serve as a consultant on teaching and college pedagogy
- Act as a liaison between the PhD students and the ME department faculty and leadership
- Act as a liaison between the CTL and the ME department, communicating information about CTL activities and programs to graduate students
- Conduct three non-evaluative videotape consultations
- Conduct consultative microteaching sessions with graduate students
- Conduct one professional development/teaching workshop
- Submit required documentation (e.g., Lead Plan, Lead network evaluations, Capstone project) to the CTL

All leads are required to attend the following events:

- May Lead Training (usually 3 days about a week after finals in May)
- Best Should Teach Lecture in August
- Fall and Spring small group meetings
- Fall Lead Network meeting
- Collaborative Preparing Future Faculty Network (COPFFN)/Spring Conference event in January
- Lead Capstone Event

G.3 Grading

The method of grading for homework, quizzes and exams will be determined by the course instructor. Some faculty have a preferred methods for each type of assignment or assessment. However, we encourage TAs to suggest different methods to grade more efficiently (so that the TA can focus on other teaching responsibilities). Examples of ways to grade more efficiently are listed below.

- Make sure that all assignments created have clear goals and instructions. This way, students will have more consistent answers that will be easier to grade.
- Use different grading scales for different assignments.
  - check +, check, check- (for quizzes, homework, response papers, quick reports or presentations, etc.)
  - 100-point numerical scale (for exams, certain types of projects, etc.)
  - pass-fail or credit-no-credit (for preparatory work)
- Grade one problem at random from each homework assignment
- Post quizzes on Canvas, so they can be graded automatically
- Limit your comments or notations to those your students can use for further learning or improvement
- Spend more time on guiding students in the process of doing work than on grading it

For more information on grading, *click here* for a great resource.

G.4 Faculty Expectations

When graduate students were asked for advice about TAing, 47% of students mentioned communication as key advice for TAing. Part of improving communications is establishing clear expectations from the instructor teaching the course. Faculty expectations of each TA should be determined before the semester begins. We recommend that all TAs meet with the faculty member instructing the course they are assigned to and use the TA expectations document to go through the expectations for each class. This document is provided to all TAs at the time they receive their TA assignment each semester. If you no longer have access to this document, please reach out to a graduate advisor.

G.5 Best Practices

General Reminders

- When paid to be a TA by the department, TAing is your main priority. For example, if a TA responsibility conflicts with lab meeting time it would be important to try to reschedule lab meeting to a time that would not conflict. If this is not possible, working with the instructor and your PI to suggest a compromise (e.g. attend lab meeting every other time) would be another option.
- Be professional with your professor and your students. Communicate openly with your professor, especially regarding semester and summer breaks.
- Set boundaries for yourself. For example, it is important to respond to students questions quickly, but you may want to communicate to your students that you will not respond to email after 11:00pm.
- You must introduce yourself to your TA class during the first week of school and send an email to the class (cc'ing your Lead TA). These introductions are extremely important because previously a lot of undergraduates did not know who their TA was.

Scheduling Office Hours

Office hours in the Engineering Center

- Note: Using the ME conference rooms is not allowed (If the professor would like the office hours held here they must book it themselves)
- To request a classroom in the Engineering Center for AFTER 5:00PM ONLY, contact the ME front desk (mefrontdesk@colorado.edu). When contacting the front desk, please include the following information:
  - Course number and title
  - Day(s) of the week for office hours or Date(s) for review sessions.
  - Start and end time. It's also helpful for the Front Desk to know whether their preferred start and end time are flexible (i.e.: prefer 6-7PM, but could also do 7-8PM).
  - Anticipated attendance. Classrooms tend to fall into 25+, 45+, 60+, 80+, and 120+ seat ranges. So those are good options to keep in mind.

Office Hours in the Idea Forge

- *For more information click here* or contact: victoria.lanaghan@colorado.edu
- Note: There are many events that occur in the Idea Forge throughout the year and office hours could move around when these events occur during your scheduled time.
- Idea Forge Commons
  - Capacity: 60 +
  - Tables for students to collaborate
  - White boards
  - Can be noisy sometimes because other students can work there
- Drop-In Design Lab
  - Capacity: 48 +
  - Tables for students to collaborate
  - Small conference rooms on the side with TVs for presentations
  - Whiteboards
  - Can be noisy sometimes because other students work there
- Classroom 271B
  - Capacity: 15
  - Tables for students to collaborate
  - Whiteboards
  - Quiet

Assignment Filing

Assignments are returned to students based on the preference of the course instructor. Most instructors will

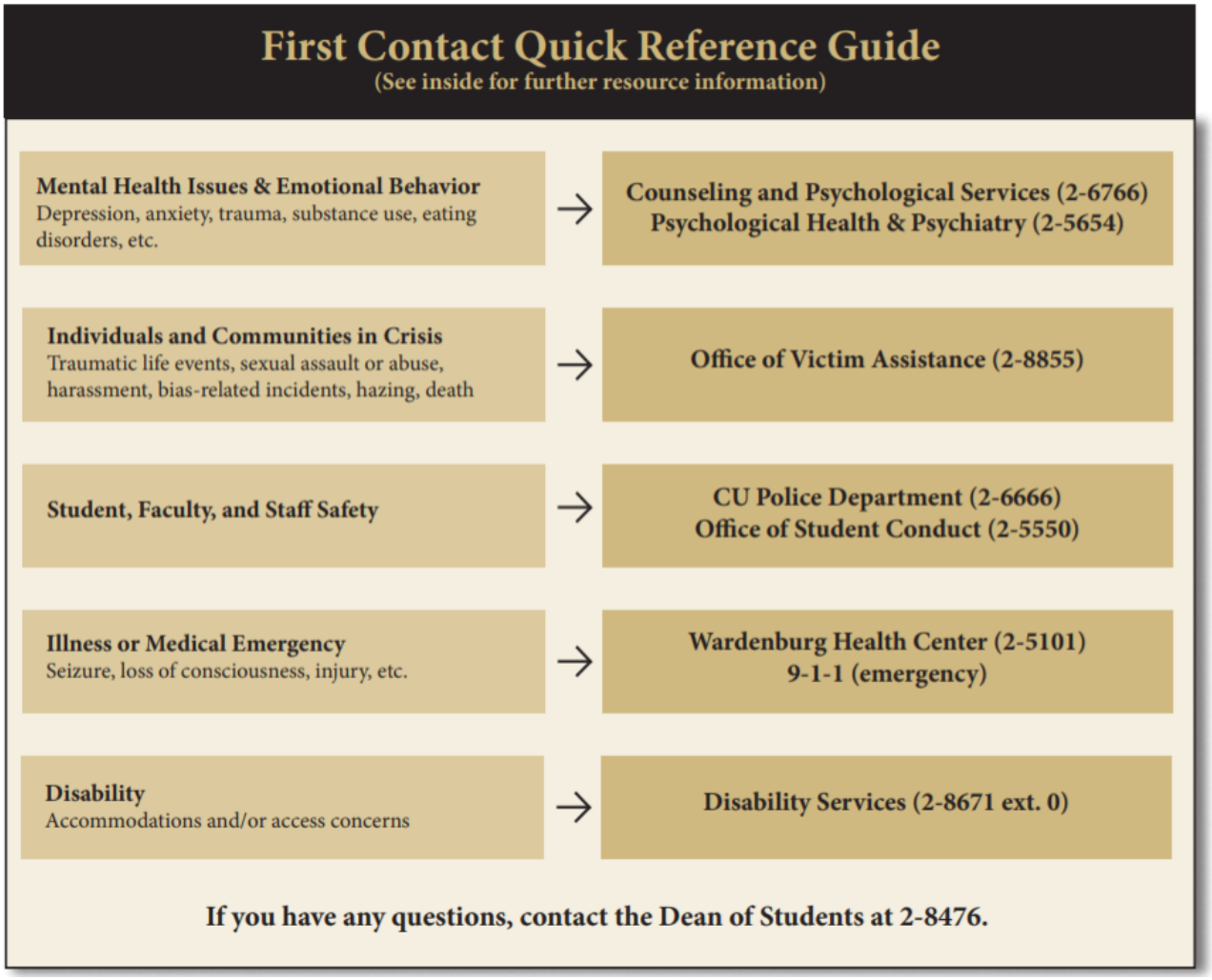
prefer that assignments are returned to students in their student folder in the filing cabinet by the front desk. It is important to organize all assignments by ME ID to make filing more efficient. When filing, the TA may ask the front desk staff if they would be able to help file the assignments only if the front desk staff is not busy or does not have other priorities from the department at the time. The TA must stay in the front desk to assist in filing the whole time.

Students in Distress

If you notice that a student in your class is in distress, take action according to the situation. This document (*click here*) provided by the graduate school can help guide how to deal with certain situations.

Remember as an employee of CU Boulder, you are a mandatory reporter. CU-Boulder policy requires any supervisor who becomes aware of a complaint of protected class discrimination and harassment and sexual harassment (including sexual assault, intimate partner abuse, and stalking) or related retaliation, to promptly report it to the *Office of Institutional Equity and Compliance (OIEC)* if the alleged perpetrator is an employee or a student.

For more information on how to respond to a disclosure, see the following *link*.



Pedagogical Resources

- *Click here for website including teaching and mentoring resources*
- *Click here for a guide specifically for TAing*

H Resources for Faculty

The graduate handbook provides an exhaustive and detailed description of graduate program requirements and processes. However, faculty frequently request further clarification on a number of topics, and explanations of these topics are provided below.

H.1 Student Advising

- **Student Expectations:** A document outlining expectations for students on Research Assistant (RA) appointments can be found here and a similar form for students on Teaching Assistant (TA) appointments can be found here. Faculty are encouraged to review and complete these forms with their RAs and TAs.
- **Dissertation Hours:** PhD students are required to have 30 dissertation hours in order to graduate. Any hours beyond 30 are unnecessary and can incur additional unnecessary expenses on sponsored projects. Faculty should work with their students and the graduate advisors to ensure that PhD students complete as close to 30 dissertation hours as possible by the end of the semester in which the PhD defense takes place. The following restrictions on dissertation hours must, however, be observed:
  - PhD students must be registered for at least 1 dissertation hour during the semester in which they complete their comprehensive exam;
  - PhD students must be registered for a minimum of 5 dissertation hours in each of the fall and spring semesters beyond completion of their comprehensive exam and defense;
  - PhD students must be registered for 5 dissertation hours during the semester in which they complete their dissertation defense;
  - PhD students may register for a maximum of 10 dissertation credits in any given semester.

  To aid with dissertation hour tracking, only the graduate advisors can enroll PhD students in dissertation hours; requests for disseration hour registration can be made by students using this form.
- **Student Support Resources:** Students with a variety of concerns, such as academics, anxiety, body image, depression, relationships, substance use and more, should contact Counseling & Psychiatric Services (CAPS), which is a confidential, on-campus mental health and psychiatric service.

  Counseling & Psychiatric Services (CAPS)
  Website: https://www.colorado.edu/counseling/
  Phone: 303-492-2277 (24/7 phone)
  Location: Center for Community, N352 (Office Hours)

  The Office of Victim Assistance (OVA) also provides free and confidential information, consultation, support, advocacy, and short term counseling services to CU students, graduate students, faculty and staff

who have experienced a traumatic, disturbing or life disruptive event.

Office of Victim Assistance (OVA)
Website: https://www.colorado.edu/ova/
Email: assist@colorado.edu
Phone: 303-492-8855 (24/7 phone); after hours press 2 to talk to a counselor
Location: Center for Community, N450
(Office Hours)

Additional campus resources can be found here and more general health resources are available here.

H.2 Funding

- **Tuition:** Detailed information on tuition and fees is available at this section of the CU Bursar's Office website. After choosing the appropriate semester on this page, PhD and MS Thesis student tuition rates are listed under the "Graduate" heading, while MS Professional tuition rates are listed under the "Professional Graduate" heading.
- **Pay Rates:** In December 2021, the department voted to increase pay rates for students on appointment (i.e., TA and RA positions) to the following
  - *Pre-comprehensive exam:* $2,755 per month
  - *Post-comprehensive exam:* $2,884 per month

  MS Thesis students on appointment are paid at the pre-comprehensive exam rate.
- **Applications for Departmental Support:** Three times per year (corresponding to the fall and spring semesters, as well as the summer), faculty advisors of mechanical engineering PhD students are given the opportunity to request departmental support (in the form of department-supported TA or RA positions, or fellowships during the summer). Announcements of the application review deadlines are made via email to the me-facstaff mailing list, and faculty can apply for funding using this form. This application form is not required for startup TA or RA requests, which can be made directly to the department financial team. Support provided through this application process is only provided for one semester at a time and separate applications must be submitted to request support in future semesters.

  Selection of students for financial support is based on need, prior departmental support received by the student, merit, and the availability of funds. Preference is given to currently enrolled PhD students, although an application may be submitted and will be reviewed for MS Thesis students. Students are selected by the graduate or executive committees, with input from the department financial team to assess need. During the fall and summer semesters, these positions provide selected students with a 50% appointment, including tuition remission and health benefits, at standard pay rates based on status (i.e., pre- or post-comps). Fellowships awarded for the summer do not include a tuition waiver/tuition remission. Faculty are expected to use any startup TA/RA positions available to them prior to requesting department support.
- **Professional MS Funding Restrictions:** According to Graduate School rules, students in our professional MS degree program cannot be placed on RA or TA appointments. These students can, however, be hired as hourly graders or research assistants. Graduate students in the MS Thesis program can be funded as RAs or TAs, with tuition remission and benefits.
- **Hourly research assistants:** Requests for hourly research assistants (i.e., hourly employees who are not part of the course support process) should be made directly to Kassie Van Pelt.

H.3 Recruiting and Admissions

- **Internal Applicants:** Current CU students seeking to switch programs (e.g., from Professional MS to PhD) should complete the change of program form. Off-cycle (e.g., spring or summer) PhD admissions can be made with the guarantee of full financial support from the student research advisor. That is, no promise of department support is made for PhD students admitted off-cycle. For current CU students wishing to transfer into the PhD program with department support as a 1st year RA or TA, the change of program

form should be completed for a fall semester matriculation, and the student application will be reviewed alongside other external applicants also seeking department support.

- **MS Thesis Incentive Program:** To strengthen and grow our MS thesis degree program, the Department of Mechanical Engineering provides $2,500 in discretionary funds per semester for each mechanical engineering MS thesis student advised by an ME faculty member. Complete details of the program are as follows:
  1. Effective the summer 2021 semester, the graduate program will provide mechanical engineering faculty with $2,500 in discretionary funds for each fall, spring and summer semester in which they advise a mechanical engineering MS thesis student(s). MS thesis students must be engaged in research during a summer semester for faculty to be eligible for discretionary funds during that summer.
  2. Funds will be available for a maximum of five semesters per MS thesis student, inclusive of any summer semesters.
  3. Funds can be used at the discretion of the faculty advisor, inclusive of purchasing lab supplies and supporting hourly employment costs for the MS thesis student.
  4. The graduate program will disperse funds to eligible faculty within the first two weeks of each fall, spring, and summer terms.
  5. Depending on faculty interest and the availability of funds, it may be necessary in the future to limit the number of MS thesis students supported by this incentive program.

  To facilitate distribution of funds, faculty are requested three times per year by email to fill out this form for both continuing and new MS thesis students in their groups.

H.4 Course Support

- **Procedure:** Course support is allocated by the graduate chair and graduate advisors 1-2 months before the start of each semester. The initial step in determining these allocations is to solicit instructor course support preferences using this form. Responses to this form are typically requested in July (for the fall semester) and in November (for the spring semester). After initial allocations are determined, they are then sent to instructors for review. Once this review has been completed, the students are then notified of their TA assignments and connected with instructors. At this point instructors can also request graders and other hourly course support using this form.
- **Calculation of Course Support:** An initial estimate of the number of support hours to assign each course is calculated as $N/4$ (minimum $N = 16$) for lecture courses and $N/3$ (minimum $N = 12$) for courses with labs/recitations, where N is the number of students enrolled in the course. Both TAs and hourly graders are used to fill the hours for courses, based in part on responses to the instructor course support preferences survey. Typically, a TA is assigned a 20 hour appointment while graders are assigned up to 10 hours, although these numbers can vary. Faculty can check their course enrollments (i.e., N) via my.cu.edu.

H.5 Curriculum

- **Online Courses:** To increase access to high-quality graduate education for non-traditional students, as well as provide access for students who find it difficult or impossible to pursue on-campus instruction, every semester we identify roughly five courses to teach fully online or in a hybrid format. Selection of these courses is guided by several principles:
  - Should be of primary interest to Professional MS students;
  - Should lend itself well to an online modality (e.g., no hands-on classes);
  - Should span a range of focus areas (e.g, bio, thermal/fluids, controls, etc.);
  - Could support one of our certificate programs or Professional MS degree requirements (e.g., industry skills);
  - Faculty should voluntarily be comfortable and willing to teach online.

  To support these classes, distance learning classrooms will be used as much possible and the graduate program works to connect instructors with resources, workshops, and trainings. Faculty will receive

$5,000 in discretionary funds for developing a new online course and $2,500 for each subsequent offering of the course. This funding can be used for additional grader and TA support to manage AV equipment, purchases of iPad, mics, etc.

- **4000/5000 Level Courses:** The CU Graduate School requires that there be a difference between 4000 and 5000 level courses that are taught as a combined 4000/5000 section. Students registered at the 5000 level are taking the course for graduate level credit, and thus the course expectations of that student must be at the graduate level. Conversely, students registered at the 4000 level are taking the course for undergraduate level credit, and thus the course expectations must be at the undergraduate level.

  It is advised that the course instructor keep track of the course requirement differences between the 4000 and 5000 level students. An ideal location to document this difference is in the course syllabus. In recent years there have been instances where a student requests changing course credit from 4000 to 5000 level, or vice-versa. The University allows for this change if the student's grade can be adjusted (or additional requirements met) per documentation provided by the course instructor. One example is where a BS/MS student enrolls in a course at the 4000 level, and after completion requests a change to 5000 level, due to some unforeseen event. In this example, the course instructor is approached to determine a grade change, or asked if additional coursework needs to be completed. While it is up to the course instructor on how to proceed, having a documented difference that can be referenced can save the course instructor significant time and hassle, in addition to maintaining Graduate School requirements.

  Course instructors should adjust their course requirements as to best fit their course. A graduate level course generally encourages deeper thought, additional workload, and/or higher expectations of the student. With that in mind, a few examples (non-exhaustive), or suggested differences that could be used to distinguish between 4000 and 5000 level students are:
  - Additional project requirements for 5000 level students
  - Additional exam problems for 5000 level students
  - Additional reading assignments and evaluations for 5000 level students
  - Additional reports, homework, or other measure of student performance for 5000 level students
  - Inclusion of a teaching role for the graduate students
- **Independent Study:** Full details of the ME Independent Study course can be found in Chapter 6.5 of the graduate handbook.
- **Internship for Credit:** Full details of the ME Internship for Credit course can be found in Chapter 6.6 of the graduate handbook.