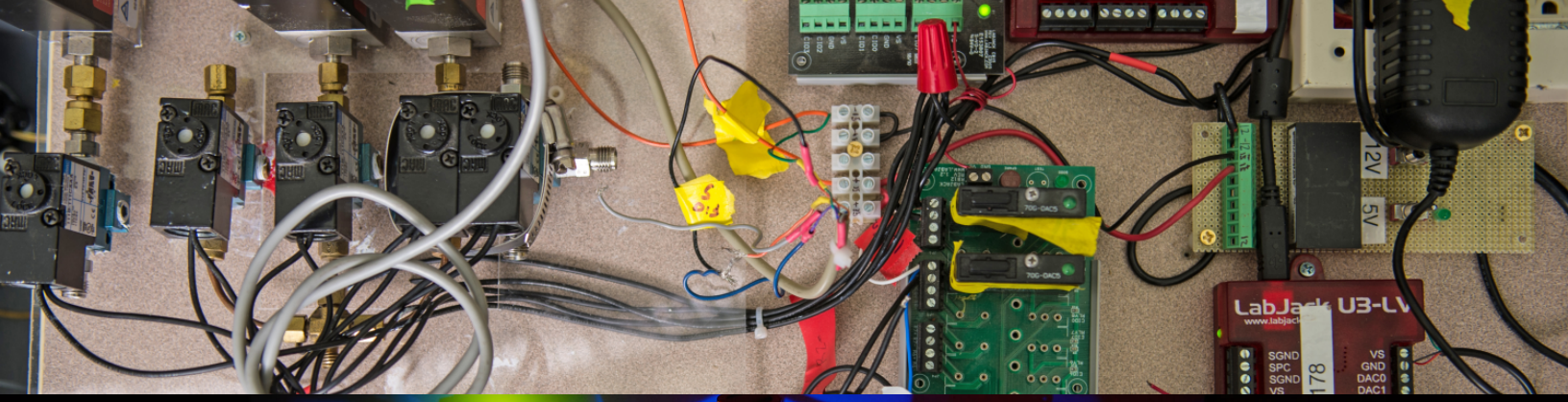
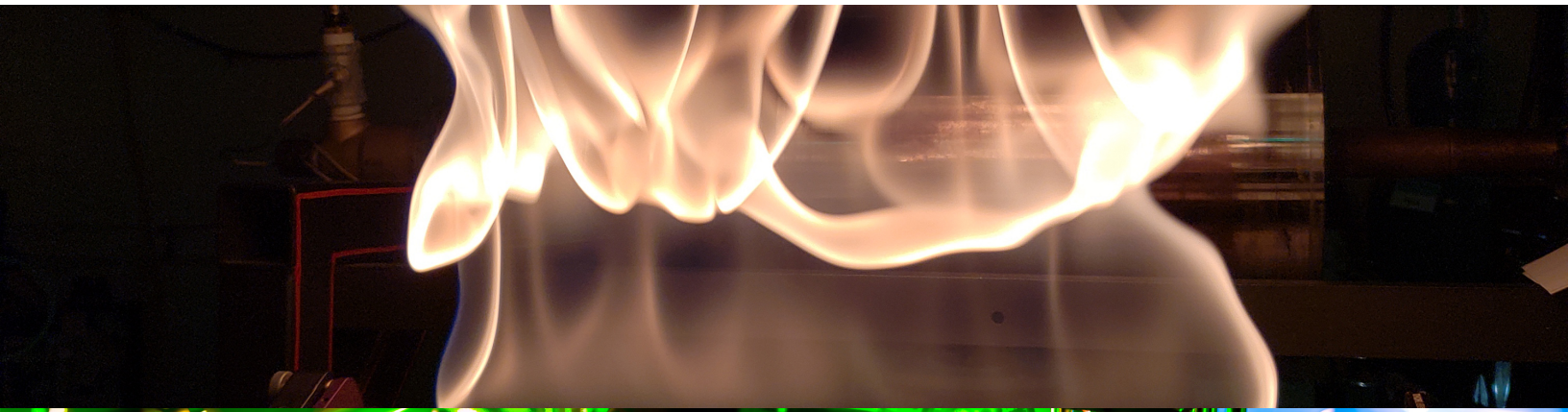


Paul M. Rady Department of Mechanical Engineering
Graduate Program Handbook

University of Colorado, Boulder

2020-2021 Academic Year



PAUL M. RADY DEPARTMENT OF MECHANICAL ENGINEERING
GRADUATE PROGRAM HANDBOOK

UNIVERSITY OF COLORADO, BOULDER

2020-2021 ACADEMIC YEAR

LAST UPDATED: AUGUST 19, 2020

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 the underlying disciplines of fluid and solid mechanics, thermal engineering, and materials science and engineering.
- **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. This program has replaced our previous joint BS/MS degree program.
  - *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 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. The department currently offers a certificate in Biomedical Engineering, which is designed to train next-generation professional engineers to interface engineering and medicine with design and problem solving to improve human health. Additional certificate options are currently being developed.

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 two graduate student representatives from the PhD program and one representative from the Master's degree program. 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 2020-2021 academic year, Prof. Peter Hamlington will serve as Graduate Program Chair, Ms. Anna

Guy will be the Graduate Advisor responsible for academic advising, and Mr. Andrew Angely will be the Graduate Advisor responsible for program administration. Mr. Jeff Glusman will serve as the Lead Teaching Assistant (TA).

Dr. Peter Hamlington
Associate Professor, Graduate Program Chair
Email: peter.hamlington@colorado.edu
Telephone: 303-492-0555
Room: ECME 222

Ms. Anna Guy
Graduate Advisor for Academic Advising
Email: anna.guy@colorado.edu
Telephone: 303-735-6346
Room: ECME 133

Mr. Andrew Angely
Graduate Advisor for Program Administration
Email: andrew.angely@colorado.edu
Telephone: 303-492-4717
Room: ECME 114

Mr. Jeff Glusman
Lead Teaching Assistant
Email: jeff.glusman@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 at https://www.colorado.edu/policies/education-teaching-research. 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: Honor Code and Procedures. Additional information is also available at https://www.colorado.edu/policies/student-honor-code-policy. 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 sen-

sitivity 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 at https://www.colorado.edu/policies/student-classroom-and-course-related-behavior.

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: https://www.colorado.edu/counseling/hours-and-contact

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: Monday-Friday 8am–5pm (summer 8:30am–4:30pm)

Additional campus resources can be found at https://www.colorado.edu/resources and more general health resources are available at https://www.colorado.edu/healthcenter/.

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:

- George Carter, Facilities Management Coordinator, george.carter@colorado.edu
- Shirley Chessman, Idea Forge Mechanical Lab Engineer, shirley.chessman@colorado.edu
- Emily Flanagan, Finance Manager, emily.flanagan@colorado.edu
- Greg Potts, Laboratory Coordinator, greg.potts@colorado.edu
- Kassie Van Pelt, HR Coordinator, kassie.vanpelt@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 2020-2021 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 here. 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 your Graduate Advisor.

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/
- **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 CU 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 of Mechanical Engineering. 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.

Note that students do not need a Master's degree to be admitted to the PhD program. Many of our 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.

Note, however, that the TOEFL/IELTS requirement is waived for international applicants for whom their native language is English, 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.

Please note that for students seeking admission to the spring 2021 semester or later, scores from either the general or subject graduate record examination (GRE) are no longer required or accepted as part of applications to the CU Department of Mechanical Engineering Graduate Program.

2.2.2 Provisional Admissions

The 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.

Please note that at the time this version of the handbook will be published, the graduate program is involved in the creation of a Bachelor's Accelerated Master's Degree option for B.S. students in Environmental Engineering who are interested in pursuing an M.S. in Mechanical Engineering. Further details will be added upon final university approval of that program.

2.2.4 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 admissions website at https://www.colorado.edu/emp/admissions-requirements.

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 at https://www.colorado.edu/graduateschool/admissions/apply. 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. Domestic PhD candidates with a 3.4 or higher undergraduate GPA who apply for admission prior to November 15, 2020 are eligible for an application fee waiver that is automatically applied at the time of application. Current CU Bachelor's degree students are eligible for the fee waiver at any time.
- **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.
- **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.

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.

As noted above, GRE scores (either general or subject) are not required as part of a graduate application for candidates seeking admission to the spring 2021 semester or later.

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 Program

Eligible students, based on the criteria outlined in Section 2.2.3, may apply to the 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, available on the graduate programs Forms & Handbook webpage.

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 at https://www.colorado.edu/emp requirements 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.

2.4 Deadlines

2.4.1 PhD Degree Program

In general, the Department of Mechanical Engineering accepts PhD applications from external (i.e., anyone not currently enrolled at CU Boulder) 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 applicant deadline:** December 15, 2020
- **Domestic applicant deadline:** December 15, 2020

Note that domestic PhD applicants with a 3.4 or higher undergraduate GPA who apply for admission prior to November 15, 2020 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/IELTS scores) must be submitted by the following deadlines for each term:

- **International applicant deadline:** October 1, 2020 (for Spring 2021) and December 15, 2020 (for Fall 2021)
- **Domestic applicant deadline:** October 1, 2020 (for Spring 2021) and December 15, 2020 (for Fall 2021)

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 Program

Eligible students interested in applying to the BAM program 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.

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 and securing an offer of funding. In particular, nearly all of our funding offers to domestic applicants go to students who attend GEARRS, although not all attendees will receive a financial offer to join the PhD program subsequent to their visit. Funding decisions are based on the availability of funds, potential fits with research groups, and compatibility with our department community and culture.

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 2020-2021 academic year, the event will be held in late February 2021; invitations will be sent out by mid-January 2021. 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 2021 will be posted, as available, at https://www.cugearrs.com/.

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 seeking an offer of funding 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, 2021
- **Master's Degree Program:** December 1, 2020 (for Spring 2021) and April 30, 2021 (for Fall 2021)

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

It is not uncommon for current CU students, both inside and outside the Department of Mechanical Engineering, to seek admission into either our Master's or PhD degree programs. For all such transfers between degree programs, the Change of Program Form should be completed.

After completing this form, and 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 enumerated in Section 2.3.

2.7.1 Transfers within the Department of Mechanical Engineering

Before initiating any program change process, we recommend students (and any faculty member they may be working with) reach out to the graduate program directly 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 (i) Professional MS (including BS/MS and BAM) to MS Thesis; (ii) MS Thesis to MS Professional; or (iii) PhD to MS Professional or 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 BS/MS, 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 engi-

neering) 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 BS/MS and 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, BS/MS and BAM students are prevented by university policy from counting any credits that were applied towards both the undergraduate and Master's degrees to a PhD degree; 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, BS/MS and 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, BS/MS and BAM students are prevented by university policy from counting any credits that were applied towards both the undergraduate and Master's degrees to a PhD degree; 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 Biomedical Engineering Certificate

Current CU graduate students interested in the 12-credit hour Biomedical Engineering certificate program can apply at any time. The following application materials can be submitted to megrad@colorado.edu:

- **Statement of purpose:** 1-2 pages explaining how the biomedical engineering 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.

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 at https://www.colorado.edu/mechanical/people/faculty.

An excellent opportunity for applicants to meet with potential advisors is during the department's annual Graduate Engineering Annual Research and Recruitment Symposium (GEARRS) for PhD students and MS Visit Day for students interest 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 of Mechanical Engineering 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 burdens.

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 webiste. 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 Boulder students switching into the PhD program, are required to establish Colorado residency within 1 year of starting the PhD program. Further detail 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 and BS/MS students, are expected to secure their own financial support. Although the department does offer a number of scholarship opportunities, detailed below, 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, with less than 5% of Master's students receiving an assistantship during the 2020-2021 academic year. 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 $16 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

Funding Type	Program		
	PhD	*MS Thesis*	*MS Professional*
Teaching Assistantship	✔	✱	✘
Research Assistantship	✔	✱	✘
Chair's Graduate Assistantship	✔	✘	✘
Dean's Graduate Innovation Assistantship	✔	✘	✘
Entrepreneurial Scholarship	✘	✔	✔
Diversity Scholarship	✘	✔	✔
University Graduate Fellowship	✔	✘	✘
Dean'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.

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 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 assisantship 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 E.

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 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 one of three special assistantships 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.

- **Dean's Graduate Assistantship:** This Assistantship is jointly funded by the Department of Mechanical Engineering and the College of Engineering and Applied Sciences. It is intended to support outstanding students during their first year of graduate studies and encourages them to pursue research in key areas of national and global need.
- **Dean's Graduate Innovation Assistantship:** The Dean's Graduate Innovation Assistantship is funded by the College of Engineering and Applied Sciences in joint recognition of outstanding faculty mentorship activities and student potential. This assistantship pairs our most qualified incoming PhD students with our most experienced and adept faculty mentors. Faculty mentors who have graduated at least 5 PhD students in the 3 preceding years are eligible to mentor a student who receives this assistantship.
- **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-preliminary exam:** $2532 per month
- **Post-preliminary exam:** $2600 per month
- **Post-comprehensive exam:** $2700 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-preliminary exam compensation rate.

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 $1000 – $4000 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 $1000 – $4000 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 Dean's Graduate Fellowships

Dean's Graduate Fellowships are awards supported by the College of Engineering and Applied Sciences. PhD applicants are automatically considered for this fellowship with their application for admission. Dean's Graduate Fellowships are awarded to applicants that show exceptional potential during the admissions process. 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 University Graduate Fellowships

University Graduate Fellowships are awards supported by the Univeristy 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.

3.6.8 Summer Fellowship

PhD students who have not received an assistantship offer for the summer term who wish to continue working in their lab may apply 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. Amounts may vary from year-to-year; Summer Fellowships for the summer 2020 term provided recipients with a total of $7885.

Application deadlines and requirements for summer fellowships will be advertised through the department's graduate student listserv each spring semester.

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, Kassie Van Pelt, 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.

Occassionally, 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.

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 year 1 (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, 2020 and March 1, 2021. Spring Grants cover travel and events taking place between March 1, 2021 and September 1, 2021. 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 $1000 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 your graduate advisor 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

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 $100 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 Anna Guy.

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 $16/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 of Science (MS) degree. While an MS degree is not required to enroll, PhD students typically 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 the CU Department of Mechanical Engineering and, as such, is expected to act professionally, ethically, and with integrity both 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	End of 1st semester
Research group selection	Research expectations form	End of 1st semester
Research development	Passing grade in MCEN 5208	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 MCEN hours	End of year 2
Comprehensive exam	Oral presentation and report	End of year 4
Professional development*	25 PDP seminars/colloquia	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. Requirements marked with an asterisk (*) can be completed by the time of the final defense; 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. All PhD students are required to take the following courses:

- MCEN 5020: Methods of Engineering Analysis I (3 credits); and
- MCEN 5028: Introduction to Research (1 credit)

Some research advisors will require that their students complete more than 30 course credits. The Department recommends that students, in addition to their graduate advisor, consult their research advisor regarding any coursework recommendations or requirements.

At the time of application, PhD students may choose from seven research focus areas to help guide the selection of courses. However, there are no formal requirements for each of these areas, and they are intended primarily to provide guidance on typical course schedules for students in different fundamental and applied research focuses. Focus areas are as follows:

- Air Quality
- Biomedical
- Materials
- Mechanics of Materials
- Micro/Nanoscale
- Robotics and Systems Design
- Thermo Fluid Sciences

Additional detail on the courses recommended in each focus area is provided in Appendix C.

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

Note that students do not need an MS degree to be admitted to the PhD program, but 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 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 6.5 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.

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 and Professional Development Requirements

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 our Research and Professional Development Requirements:

- **Research Development Requirement [formerly Professional Development Workshops (PDWs)]:** For all students starting in Fall 2019 or later, this requirement is fulfilled by obtaining a passing grade in MCEN 5208: Introduction to Research (this course is graded on a pass/fail, or P/F, basis). This course 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. For PhD students who started in a term prior to Fall 2019, this requirement may be fulfilled either by completion of MCEN 5208 or by completing 7 Professional Development Workshops (PDWs) on an *ad hoc* basis. Those choosing to complete the PDWs on an *ad hoc* basis can submit workshops and seminars for credit using the PDW Attendance Form. For students starting in Fall 2019, the Research Development Requirement must be completed before proceeding to post-preliminary exam status. For students starting prior to Fall 2019, the Research Development Requirement must be completed no later than the end of the Fall 2020 semester.

- **Professional Development Requirement**: The Department offers many seminars and colloquia throughout the year delivered by notable engineering leaders in education, research, and industry. These seminars afford students the opportunity to expand substantive knowledge, network, and gain exposure to diverse styles of research presentation. In order to satisfy their Professional Development Program (PDP) requirements, PhD students must attend 25 seminars/colloquia during the course of their time at CU. Credit is received for seminars attended by filling out the PDP Seminar Attendance Form. For those students who started at CU prior to Fall 2019, and who plan to complete their Research Development Requirement on an *ad hoc* basis (requiring 7 PDWs), a total of 30 PDP seminars are required; these seminars are again tracked using the PDP Seminar Attendance Form. Note that there is no limit to how many out of department seminars can be used to satisfy the Professional Development Requirement, and examples of approved seminars include departmental seminar series, faculty candidate seminars, PhD and MS Thesis defenses, etc. Current students who have completed at least one semester of MCEN 5027 Graduate Seminar will be credited 10 seminars for each completed semester. Please note that only seminars occurring after the date of matriculation in our graduate program can be counted towards the PDP requirement. That is, there is no retroactive credit for seminars attended prior to becoming a graduate student in ME.

Student progress toward completion of the Professional Development Requirement is tracked through the "ME Graduate Professional Development Program" course on the Canvas platform. For students who started at CU prior to Fall 2019, this is also where the Research Development Requirement is tracked (as indicated by the number of PDWs completed). If you have any questions about your progress in fulfilling these requirements, please contact the Graduate Advisor at megrad@colorado.edu.

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 seven topic exams. Concept inventories are provided for each topic in Appendix D and peer-led oral exam practice efforts will be organized to facilitate growth with oral defense. The list of topics and their corresponding preparatory courses are listed below:

- **BioM**^{3}: 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 two faculty. The committee cannot include your 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 250 word presentation abstract, including title and any relevant references, 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.

Depending on how much research progress a student has made, the exam may consist primarily of a literature review, a plan for future research, or the presentation of preliminary research results. The committee will ask challenging questions of the student in order to test the bounds of the student's knowledge and research potential.

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.

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.

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.

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:

- 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.

4.7 Annual Survey

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.

4.8 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.

4.9 Cooperative Programs

4.9.1 Interdisciplinary Quantitative Biology Program

IQ Biology is a Graduate PhD Certificate through CU Boulder's BioFrontiers Institute. The certificate is earned in concordance with a CU Boulder degree-granting PhD program with a partner department. Students learn Interdisciplinary Quantitative skills, while also gaining in-depth knowledge of their field with one of eleven partner departments.

Through IQ Biology, students learn the essential competencies demonstrated by knowledgeable, and well-rounded researchers who collaborate effectively across disciplines. These competencies are attained in a number of ways, including cross-departmental lab rotations, courses, interdisciplinary projects, outreach activities, and science engagement.

Please visit https://www.colorado.edu/certificate/iqbiology/ for more information about program details and application procedures.

4.9.2 Materials Science Program

The Materials Science and Engineering (MSE) Program is an interdisciplinary PhD and MS program aimed at providing a rigorous education in materials science and engineering and the fundamental physics, engineering, chemistry and biology that underlie this discipline. Educational goals are achieved through both coursework and training in cross-disciplinary research supervised by one or more science and engineering faculty members.

The program offers six unique tracks of study: electronic, magnetic and photonics materials; soft materials; structural materials; materials for energy; biomaterials; and computational materials science.

Please visit https://www.colorado.edu/mse/ for more information about program details and application procedures.

4.9.3 Environmental Engineering Program

The Environment Engineering graduate program is administered by faculty from multiple College of Engineering and Applied Sciences departments, including Aerospace Engineering Science; Civil, Environmental, and Architectural Engineering; and Mechanical Engineering. Courses required for the program are offered through the collaborating departments, with student credit hours assigned accordingly.

Faculty teaching and research area of interest include:

- Water Sustainability
- Natural systems / Non-point Source: Fate, Transport and Treatment
- Air Quality Monitoring and Modeling

Please visit https://www.colorado.edu/even/ for more information about program details and application procedures.

5 Master's Degree Programs

5.1 Overview

Master's degree students in the CU Department of 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. Some current students are also pursuing concurrent Bachelor's of Science (BS) and MS degrees through the now-discontinued combined BS/MS program, which has slightly different policies than the BAM program.
- **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 Department of Mechanical Engineering 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 one 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.

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

The Professional MS Degree program offers courses in five focus areas, including a flex option that allows students to combine courses across the academic spectrum to meet their specific needs:

- Biomedical
- Clean technology
- Computational modeling, simulation & analysis
- Design
- Flex option

The only focus area that has specific course requirements is Design, as outlined in Section 5.4.2. Students interested in pursuing any of the other focus areas can enroll in any combination of coursework that they would like, although a list of relevant courses for each focus area is provided in Appendix C.

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:** 15 Professional Development Program (PDP) seminars must be completed during the course of the Master's degree. Further details on this requirement and the procedure for submitting PDP credits is described in Section 5.4.7.

5.4.2 Design Program

The objective of the Design Program is to develop design engineers that are industry oriented, experimentally-prepared, self-directed, creative, innovative, and differentiated professionals with project management experience. The cornerstone of this unique program is a group of core, comprehensive design courses:

- MCEN 5055 Advanced Product Design
- MCEN 5045 Design for Manufacturability
- MCEN 5065 Graduate Design I (prereq MCEN 5055 Advanced Product Design)
- MCEN 5075 Graduate Design II (prereq MCEN 5065 Graduate Design I)

The first course in this sequence is Advanced Product Design (APD). APD is a studio class that focuses on consumer product and user-centered design and helps equip students with the tools necessary to conceptualizeinnovative designs.

APD is followed in the spring by Design for Manufacturability (DFM). DFM teaches students how to take theirconceptual designs generated in APD, and transform them into products which are ready for manufacturing.

Although both DFM and APD are offered in both fall and spring semesters, we encourage students to take the sequence of courses in order as outlined above.

Following APD and DFM, students complete Graduate Design I & II. This yearlong project based course must be completed in a fall/spring sequence. In Graduate Design, teams composed of 3-4 students complete an industry-sponsored design project. Teams collaborate regularly with a mentor from the sponsoring company and a faculty advisor on all project and financial management details of the project. Teams are tasked with delivering a near turn-key product at the end of the 9-month project.

Graduate students who have questions about the Design Program or would like more information should contact Prof. Mark Rentschler at mark.rentschler@colorado.edu or Prof. Dan Riffell at daniel.riffell@colorado.edu.

5.4.3 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. Courses are offered in eight focus areas:

- Air Quality
- Biomedical
- Design
- Energy and Environment
- Materials
- Mechanics of Materials
- Microsystems
- Robotics and Control

No courses are required for any of these areas, rather, they are intended primarily to provide guidance on typical course options for students in different fundamental and applied research areas. A list of relevant courses for each focus area is provided in Appendix C.

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 (1 credit)
  - 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.
- **Professional development:** 10 PDP seminars must be completed during the course of the MS Thesis degree. Further details on this requirement and the procedure for submitting PDP credits are provided in Section 5.4.7.
- **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.

  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.

5.4.4 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.

5.4.5 Concurrent BS/MS Degree Program

The concurrent BS/MS program was replaced by the BAM program, effective July 1, 2019. Students currently with the department that were admitted to the BS/MS program will continue to adhere to BS/MS policy in pursuit of their degrees. Both BS and MS degrees will be awarded simultaneously when requirements for both

degrees are met. Further details on the concurrent degree program can be found on the registrar website.

To comply with Title IV Higher Education regulations, students pursuing a concurrent BS/MS degree will automatically be changed to graduate status after the completion of 145 credit hours.

5.4.6 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 Department of Mechanical Engineering credits. 6 additional credits must be completed and can be taken outside the department, if desired.
- **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.
- **Professional development:** 15 PDP seminars must be completed as part of the mechanical engineering Master's degree. Further details on this requirement and the procedure for submitting PDP credits is described in Section 5.4.7.
- **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.

5.4.7 Professional Development Program

The Department of Mechanical Engineering is committed to educating well-rounded Master's 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. These seminars afford students the opportunity to expand substantive knowledge, network and gain exposure to diverse styles of research presentation.

In addition to coursework requirements, all Master's students must attend seminars/colloquia as part of the Professional Development Program (PDP) in order to graduate. The required number of PDP seminars are:

- **Professional MS:** 15 PDP seminars
- **MS Thesis:** 10 PDP seminars
- **BAM and BSMS:** 10 PDP seminars
- **Dual Degree in Engineering Management and ME:** 15 PDP seminars

Credit is received for seminars attended by filling out the PDP Seminar Form. There is no limit to how many

out of department seminars can be used to satisfy the Professional Development Requirement, and examples of approved seminars include departmental seminar series, faculty candidate seminars, PhD and MS Thesis defenses, etc.

Student progress toward completion of the Professional Development Program requirement is tracked through the "ME Graduate Professional Development Program" course on the Canvas platform. If you have any questions about your progress in fulfilling these requirements, please the Graduate Advisors at megrad@colorado.edu.

5.4.8 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 6.5 of Chapter 6.

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.

5.6 Certificates

Professional MS students have the option to pursue a 9-credit (3 courses) graduate certificate in Biomedical Engineering as they fulfill the 30 credit hour coursework requirement.

5.6.1 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.

Admissions procedures and additional information can be found in Chapter 2.

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 at https://www.colorado.edu/registrar/students/calendar. 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 6.4. 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 at https://www.colorado.edu/reg

6.3 Transcripts

Official transcripts for current and previous graduate students can be ordered online from the Office of the Registrar at https://www.colorado.edu/registrar/students/transcripts. Unofficial transcripts can be downloaded anytime by students through the educational portal.

6.4 Independent Study

An independent study course is defined as research study requiring a high level of self-directed learning. Thislearning 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 statedobjectives. This work may be experiential, directed reading or independent research supervised by a facultymember and approved by the mechanical engineering graduate chair.

6.4.1 Guidelines

A number of activities are specifically prohibited as independent study work. Included here are such activitiesas internships, volunteer or paid work in a university department, volunteer work of other kinds, work in abusiness, extra work in a class, and work completed elsewhere. Strictly prohibited are independent study asa substitute for a regular course offering. Independent study will normally consist of directed research whichleads to the preparation of a substantive presentation of findings, usually in the form of a written paper orreport. 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.

6.4.2 Requirements

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 3.3.
- 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.

6.4.3 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 and/or 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.
- The number of allowable independent study credits for any student should be limited to less than or equal to 25% of the total coursework credits required by the student's degree program (7 credits maximum).

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.

6.4.4 Documentation

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.

6.5 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 at CU.

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

6.6 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.

6.7 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.

6.8 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.

6.9 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.

6.10 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.

6.11 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".

6.12 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

6.13 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.
- As outlined in Sections 4.4.5 and 5.4.7, 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 D.

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.

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
- Professional Development Program (PDP) attendance form
- Professional Development Workshop (PDW) attendance 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

Focus Area Course Guidance

C.1 Air Quality

Research and coursework in the Air Quality track encompass a broad range of topics from air quality monitoring, climate change, atmospheric chemistry and dynamics, and health impacts, to air pollution engineering, control and policy. Research addresses monitoring and impact assessment on scales spanning from local (building-scale) to regional and global; from fundamental science to applied social science and community-driven research; and from computational studies to field-based experiments in remote locations. The University of Colorado is uniquely situated amongst one of the world's greatest ecosystems of academic institutions and national labs engaged in atmospheric research. The National Renewable Energy Laboratory (NREL), National Center for Atmospheric Research (NCAR), National Oceanic and Atmospheric Administration (NOAA), and National Institute of Standards and Technology (NIST) are located within 30 minutes of CU Boulder.

Required:

- MCEN 5020 Methods of Engineering Analysis

Strongly Recommended:

- MCEN 5021 Fluid Dynamics
- MCEN 5131 Air Pollution Control Engineering
- CHEM 5151 Atmospheric Chemistry

Recommended:

- MCEN 5228 Air Quality Measurements
- MCEN 5161 Aerosols
- MCEN 5141 Indoor Air Pollution
- CHEM 5152 Atmospheric Chemistry 2

Specialized Courses/Electives:

- MCEN 5022 Classical Thermodynamics
- MCEN 5035 Sustainable Energy
- MCEN 5040 Methods of Engineering Analysis II
- MCEN 5042 Heat Transfer
- MCEN 5057 Environmental Modeling

- MCEN 5151 Flow Visualization
- MCEN 5228 Chemical Kinetics for the Thermal Sciences
- MCEN 5228 Cookstove Assessment
- MCEN 5228 Environmental Law
- MCEN 5228 Environmental Toxins
- MCEN 5228 Inverse Methods
- MCEN 5228 Micro-Scale Heat Transfer
- MCEN 5228 Nanotechnology for Environmental Sustainability
- MCEN 5228 Numerical Methods
- MCEN 7221 Turbulence
- ATOC 5050 Atmospheric Dynamics
- ATOC 5600 Clouds and Aerosols
- CHEM 3311 Organic Chemistry 1
- CHEM 4181 Instrumental Analysis
- CHEM 4531 Physical Chemistry 2
- CHEM 5161 Analytical Spectroscopy
- CHEM 5181 Mass Spectrometry & Chromatography
- CVEN 6833 Advanced Data Analysis
- CVEN 5404 Environmental Engineering Chemistry
- CVEN 5424 Environmental Organic Chemistry
- CVEN 5454 OR ASEN 5047 Statistics

C.2 Biomedical

Biomedical engineering is a field which employs quantitative methods in physics, chemistry and biology to develop innovative medical technologies. At CU, we draw from our strengths in biomechanics – the application of classical and quantum mechanics to analyze biological systems – and product design to tackle current and emerging medical challenges, including those in the areas of biomaterials, tissue engineering, imaging and theranostics.

Required:

- MCEN 5020 Methods of Engineering Analysis

Recommended (to best prepare for area preliminary exams):

- MCEN 5021 Fluid Dynamics
- MCEN 5022 Thermodynamics
- MCEN 5023 Solid Mechanics
- MCEN 5024 Materials Chemistry
- MCEN 5040 Methods of Engineering Analysis 2
- MCEN 5042 Heat Transfer
- MCEN 5117 Anatomy & Physiology

Specialized Courses/Electives:

- MCEN 5898 Independent Study (clear âĂIJbioâĂİ focus, 3-6 credits total)
- MCEN 5055 Advanced Product Design
- MCEN 5064 Soft Machines
- MCEN 5065 Graduate Design 1
- MCEN 5075 Graduate Design 2
- MCEN 5117 Anatomy & Phys for Engin I
- MCEN 5127 Biomedical Ultrasound

- MCEN 5137 Anatomy & Phys for Engin II
- MCEN 5154 Biomembranes & Biocolloids
- MCEN 5228 Biomechanics
- MCEN 5228 Biomimetic Materials
- MCEN 5228 Cells, Molecules and Tissues
- MCEN 5228 Materials in Medicine or
- MCEN 5228 Mechanics of Soft Matter
- MCEN 5228 Mechanobiology
- MCEN 5228 Medical Device Design
- MCEN 5228 Micro/Nano/Bio
- MCEN 5228 Surface Forces in Biology
- MCEN 6228 Microfluidics for Biomedical Applications
- CHEN 5085 Biomaterials
- ECEN 5011 Biologically Engineered Control Systems
- ECEN 5011 Design of Medical Devices
- MCDB 6440 Molecular Bio & Micro/Nano-Scale Engineering
- ASEN 5016 Space Life Sciences
- ASEN 5506 Bioastronautics Sem (1 credit)
- ASEN 6506 Bioatronautics Sem (presentation, 2 Credits)
- CHEN 5128 Applied Stats in R&D
- IPHY 5730 Motor Control
- IPHY 5800 Adv Stats and Res Methods
- IPHY 6010 Physiology of Aging
- IPHY 6650 Cellular Cardiovascular Physiology
- IPHY 6660 Locomotion Energetics and Biomechanics

C.3 Materials

The Materials program offers students a mixture of high quality education and cutting-edge research. Faculty members carry out research in many different areas including polymers, thin films, soft actuators, battery materials, laser ultrasonics, flash sintering, nanomaterials for energy, heat transfer and meta materials. Graduate students have ample opportunities to choose to specialize in various aspects of materials science and engineering.

Required:

- MCEN 5020 Methods of Engineering Analysis

Strongly Recommended:

- MCEN 5024 Materials Chemistry Structure
- MCEN 5044 Mechanical Behavior of Materials
- MCEN 5034 Thermodynamics Kinetics of Materials
- MCEN 5228 Introduction to Polymers
- MCEN 5023 Solid Mechanics or CVEN 5131 Continuum Mechanics Elasticity

Specialized Courses/Electives:

Biomaterials Interest

- MCEN 5044 Mechanical Behavior of Materials
- MCEN 5228 Biomechanics
- MCEN 5228 Materials in Medicine
- MCEN 5228 Biocolloids/Biomembranes

- MCEN 5228 Micro/Nano/Bio
- MCEN 6184 Structure Properties of Polymers
- MCEN 6228 Microfluidics for Biomedical Applications
- CHEN 5710 Molecular Basis of Biological Behavior
- CHEN 5450 Polymer Chemistry
- PHYS 5130 Biological Electron Microscopy: Principles Recent Advances

Mechanics of Materials Interest

- MCEN 5044 Mechanical Behavior of Materials
- MCEN 5228 Introduction to Polymers
- MCEN 5228 Mechanics of Soft Materials
- MCEN 5228 Mechanical Failure of Materials
- MCEN 5228 Thin Film Materials
- MCEN 6184 Structure Properties of Polymers
- ASEN 5519 Advances in Materials Processing

Energy Materials Interest

- MCEN 5154 Energy Conversion Storage
- MCEN 5228 Microscale Heat Transfer

Nanomaterials Interest

- PHYS 3220 Quantum Mechanics 1
- MCEN 5115 Mechatronics Robotics
- MCEN 5228 Intro to Nanoscience
- MCEN 5528 Nanomaterials

Electrical/Optical Materials Interest

- ECEN 5345 Introduction to Solid State
- ECEN 5365 Semiconductor Materials Devices 1
- ECEN 6365 Semiconductor Materials Devices 2
- ECEN 5385 Optical Properties of Materials
- MCEN 5636 MEMS 1
- MCEN 5010 Microsystems Integration
- MCEN 5228 Intro to Nanoscience
- MCEN 5228 Nanomaterials

C.4 Mechanics of Materials

Mechanics of materials is an area focusing on quantitative description of the motion and deformation of solid materials subjected to forces, temperature changes, electrical voltage or other external stimuli. At CU, we apply theoretical modeling, computational simulation and experimental characterization to study a wide range of soft materials, from biological tissues and gels to smart polymers. Our applications cover a long list of current and emerging technologies including tissue engineering, membrane filtration, stretchable electronics, smart materials, medical robots and innovative surgical devices.

Required:

- MCEN 5020 Methods of Engineering Analysis

Strongly Recommended:

- MCEN 5023 Solid Mechanics or CVEN 5131 Continuum Mechanics Elasticity
- MCEN 5173, ASEN 5007 or CVEN 5511 Finite Element Analysis

Recommended:

- MCEN 5021 Fluid Dynamics
- MCEN 5024 Materials Chemistry Structure
- MCEN 5044 Mechanical Behavior of
- Materials
- MCEN 5034 Thermodynamics Kinetics of Materials

Specialized Courses/Electives:

Mechanics Interest

- MCEN 5064 Soft Machines
- MCEN 5228 Mechanics of Composite Materials
- MCEN 5228 Mechanics of Soft Materials
- MCEN 5228 Thin Film Materials
- CVEN 5161 Advanced Mechanics of Materials I
- CVEN 6161 Advanced Mechanics of Materials 2
- CVEN 7161 Fracture Mechanics
- PHYS 5210 Theoretical Mechanics

Computational Mechanics Interest

- MCEN 6228 Numerical Methods
- CVEN 7511 Comp Mech of Solids Structures
- ASEN 6367 Advanced Finite Element Meth.
- ASEN 5417 Num Methods for Differential Equations
- ASEN 6107 Nonlinear Finite Element Methods

Design Mechanics Interest

- MCEN 5248 Microsystems Design
- MCEN 5125 Optimal Design
- ASEN 5519 Design Optimization
- ASEN 5218 Large Space Structure Design
- ASEN 5148 Spacecraft Design

Materials Interest

- MCEN 5044 Mechanical Behavior of Materials
- MCEN 5034 Thermodyn Kinetics of Materials
- MCEN 5228 Biomimetic Materials
- MCEN 5228 Ceramics
- MCEN 5228 Introduction to Polymers
- MCEN 5228 Materials Chemistry Structure
- MCEN 5228 Mechanics of Soft Materials
- MCEN 5228 Thin Film Materials
- MCEN 6184 Structure Properties of Polymers
- ASEN 5519 Advances in Materials Processing

Micro/Nanomechanics Interest

- MCEN 5228 Materials Chemistry Structure
- MCEN 5636 MEMS 1
- MCEN 5248 MEMS 2

- PHYS 3220 Quantum Mech Atomic Physics 1
- PHYS 4410 Quantum Mech Atomic Physics 2
- PHYS 4230 Thermodynamics Statistical Dynamics
- PHYS 4340 Solid-State Physics
- PHYS 5250 Intro Quantum Mechanics 1
- CHEM 557 Surface Science

C.5 Micro/Nanoscale

Micro/Nanoscale research involves micro- and nano-electromechanical systems (MEMS and NEMS) for transducers, sensors and actuators. Strengths include atomic, nano, micro fabrication technologies and advanced packaging. Visible, active programs are also underway in nano and microscale characterization, simulation and design of materials.

Required:

- MCEN 5020 Methods of Engineering Analysis

Strongly Recommended:

- MCEN 5636 MEMS I
- MCEN 5010 Microsystems Integration

Recommended:

- MCEN 5023 Solid Mechanics
- MCEN 5024 Materials Chemistry Structure
- MCEN 5021 Fluid Dynamics
- MCEN 5042 Heat Transfer

Specialized Courses/Electives:

- MCEN 5021 Fluid Dynamics
- MCEN 5023 Solid Mechanics
- MCEN 5024 Materials Chemistry Structure
- MCEN 5042 Heat Transfer
- MCEN 5115 Mechatronics Robotics
- MCEN 5173 Finite Element Analysis
- MCEN 5183 Mechanics of Composites
- MCEN 5228 Mechanical Failure of Materials
- MCEN 5228 Bio/Micro/Nano
- MCEN 5228 Nanoscience
- MCEN 5228 Microscale Heat Transfer
- MCEN 6228 Microfluidics for Biomedical Applications
- ASEN 5022 Dynamics of Aerospace Structures
- ASEN 5519 Modeling and Simulation of Microfluidic Systems
- ASEN 5519 Design Optimization
- ECEN 5324 Microsystem Packaging
- ECEN 5375 Microstructures Laboratory

C.6 Robotics and Systems Design

Robotics and systems design research focuses on identifying fundamental principles and methodologies that enable engineered systems to exhibit intelligent, goal-oriented behavior, and developing innovative instruments to monitor, control and manipulate systems. Faculty and students participate in several major sponsored research centers, including the Army's Micro Autonomous Science and Technology (MAST) CTA, and

the AFOSR Center of Excellence on Nature-Inspired Flight Technologies and Ideas (NIFTI). Research in the Robotics and Systems Design Area typically leverages three core competencies in service to diverse needs in such areas as healthcare, security, education, space and ocean exploration, and autonomous systems in air, land and underwater.

Required:

- MCEN 5020 Methods of Engineering Analysis

Strongly Recommended:

The material in the following courses are pre-requisite for the electives below. If you already have the background in these areas, then you may not need to take the courses. See the description in the classes and consult with your thesis advisor for more information.

- MCEN 5228 Feedback Control
- ASEN 5014 Linear Control Systems (prereq MCEN 5228 Feedback Control)

Specialized Courses/Electives:

- MCEN 6228 Robust Multivariable Control (prereq ASEN 5014 Linear Control Systems)
- MCEN 5228 Industrial Automation
- MCEN 5064 Soft Machines
- MCEN 5115 Mechatronics and Robotics
- MCEN 5125 Optimal Design
- CSCI 5302 Advanced Robotics (prereq: command of the Linux operating system, programming in C++ and/or Python, computer with Ubuntu 14.04)
- CSCI 7000 Swarm Intelligence (prereq: Discrete algorithms)

C.7 Thermo Fluid Sciences

Thermo Fluid Sciences research in the Department of Mechanical Engineering is focused on a wide range of both fundamental and applied problems related to energy conversion, heat and mass transfer, combustion, and fluid mechanics. Experimental, theoretical, and computational approaches are used to study thermal-fluids phenomena covering an enormous range of scales, from heat transport at micro and nano scales to the properties of the atmosphere and ocean over many kilometers.

Required:

- MCEN 5020 Methods of Engineering Analysis

Strongly Recommend:

- MCEN 5021 Introduction to Fluid Dynamics
- MCEN 5022 Classical Thermodynamics
- MCEN 5042 Heat Transfer

Specialized Courses:

- MCEN 5023 Solid Mechanics
- MCEN 5024 Materials Chemistry Structure
- MCEN 5032 Sustainable Energy
- MCEN 5034 Thermodynamics of Materials
- MCEN 5040 Methods of Engineering Analysis II
- MCEN 5041 Advanced Fluid Mechanics I
- MCEN 5044 Mechanical Behavior of Materials
- MCEN 5121 Compressible Flows

- MCEN 5122 Statistical Thermodynamics
- MCEN 5131 Air Pollution Control
- MCEN 5141 Indoor Air Pollution
- MCEN 5151 Flow Visualization
- MCEN 5152 Introduction to Combustion
- MCEN 5154 Energy Conversion Storage
- MCEN 5161 Aerosols
- MCEN 5173 Finite Element Analysis
- MCEN 5183 Mechanics of Composite Materials
- MCEN 5228 Environmental Law
- MCEN 5228 Inverse Methods
- MCEN 5228 Microscale Heat Transfer
- MCEN 5228 Numerical Methods in Engineering Sciences
- MCEN 5228 Phononics and Thermal Metamaterials
- MCEN 6001 Reacting Flows
- MCEN 6184 Structure and Props. of Polymers
- MCEN 6228 Kinetics of Chemically Reacting Systems
- MCEN 6228 Microfluidics for Biomedical Applications
- MCEN 6278 Acoustics
- MCEN 7122 Combustion Phenomena
- MCEN 7123 Dynamics of Continuous Media
- MCEN 7221 Turbulence
- APPM 5380 Modeling in Applied Mathematics
- APPM 5520 Intro. to Mathematical Statistics
- APPM 5560 Markov Proc, Queues, Monte Carlo Sim
- APPM5720 Data and High-Dimensional Dynamical Systems
- APPM 6520 Mathematical Statistics
- APPM 6550 Intro to Stochastic Processes
- APPM 6640 Multigrid Methods
- APPM 7300 Nonlinear Waves and Integrable Equations
- ASEN 5007 Introduction to Finite Elements
- ASEN 5053 Rocket Propulsion
- ASEN 5063 Gas Turbine Propulsion
- ASEN/ATOC 5235: Introduction to Atmospheric Radiative Transfer and Remote Sensing
- ASEN 5315 Ocean Modeling
- ASEN 5417 Num. Methods for Diff. Equations
- ASEN 5519 Ener Sys for Earth and Aero Application
- ASEN 6013 High Speed Propulsion
- ASEN6519 Experimental Fluid Mechanics
- ASEN 6367 Adv Fin Elem Meth for Plates, Shells, Solids
- ASEN 6517 Comp. Methods in Dynamics
- ATOC 5050 Intro. to Atmospheric Dynamics
- CHEN 5220 Mass Transport
- CHEN 5360 Catalysis and Kinetics
- CHEN 5370 Intermed. Chemical Eng. Thermodynamics
- CHEM 5151 Atmospheric Chemistry
- CSCI 5454 Design Analysis of Algorithms
- CSCI 7111 Topics in Parallel Processing

- CVEN 5313 Environmental Fluid Mechanics
- CVEN 5488 Comp Modeling in Geotechnical Enginrng
- CVEN 5830 Energy Technology and Policy
- CVEN 7511 Comp Mechanics of Solids and Structures
- ECEN 5017 Conventional and Renewable Energy Issues
- ENER 5001 (ENVS 5820) Renewable Energy Policy
- ENER 5002 (BADM 6930) Commercializing Sustainable Energy Technologies

D

Oral Prelim Concept Inventories

Concept inventories are provided in this appendix for each of the oral preliminary exam topics: BioM^3 (Biomedical, Biomaterials, and Biomechanics), 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.

Corresponding preparatory courses for each topic are listed below:

- **BioM^3**: 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.

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

At the end of this appendix, recommendations for preparing for both oral and research preliminary exams are provided by Prof. John Daily.

D.1 Biomedical, Biomaterials, and Biomechanics (BioM^3)

Fall 2020 Faculty Lead: Alaa Ahmed (alaa@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. In addition, students will be responsible for information covering two "systems" from Units 4-9 of the course textbook (e.g. nervous, cardiovascular, respiratory, gastrointestinal, renal, endocrine), which closely align with their planned research interests. The BioM^3 preliminary exam will consist of a question and answer period covering fundamental topics and systems.

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
  Chapter 2.9 – ATP Production I: Glycolysis
  Chapter 2.10 – ATP Production II: The TCA Cycle and Oxidative Phosphorylation
  Chapter 2.11 – ATP Production III: Fatty Acid Oxidation and Amino Acid Oxidation
- *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

D.2 Controls

Fall 2020 Faculty Lead: Rob MacCurdy (maccurdy@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

D.3 Fluid Dynamics

Fall 2020 Faculty Lead: Debanjan Mukherjee (debanjan@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.

D.4 Heat Transfer

Fall 2020 Faculty Lead: Jeff Knutsen (jeffrey.knutsen@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.

D.5 Materials

Fall 2020 Faculty Lead: Carson Bruns (carson.bruns@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.

D.6 Mechanics

Fall 2020 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.

D.7 Thermodynamics

Fall 2020 Faculty Lead: Greg Rieker (greg.rieker@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
- Chemical reactions
- Chemical and phase equilibrium

For every problem you should be able to:

- Gather and collate given information âĂŞ what is known, what are you trying to find, what assumptions will you 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

D.8 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.

Resources for Teaching Assistants

E.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)

E.2 Lead Teaching Assistant (TA)

The lead TA 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 TA will receive training in academic management, academic leadership, college pedagogy, collegial teamwork and project management.

Responsibilities of the lead TA 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

E.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.

E.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.

E.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

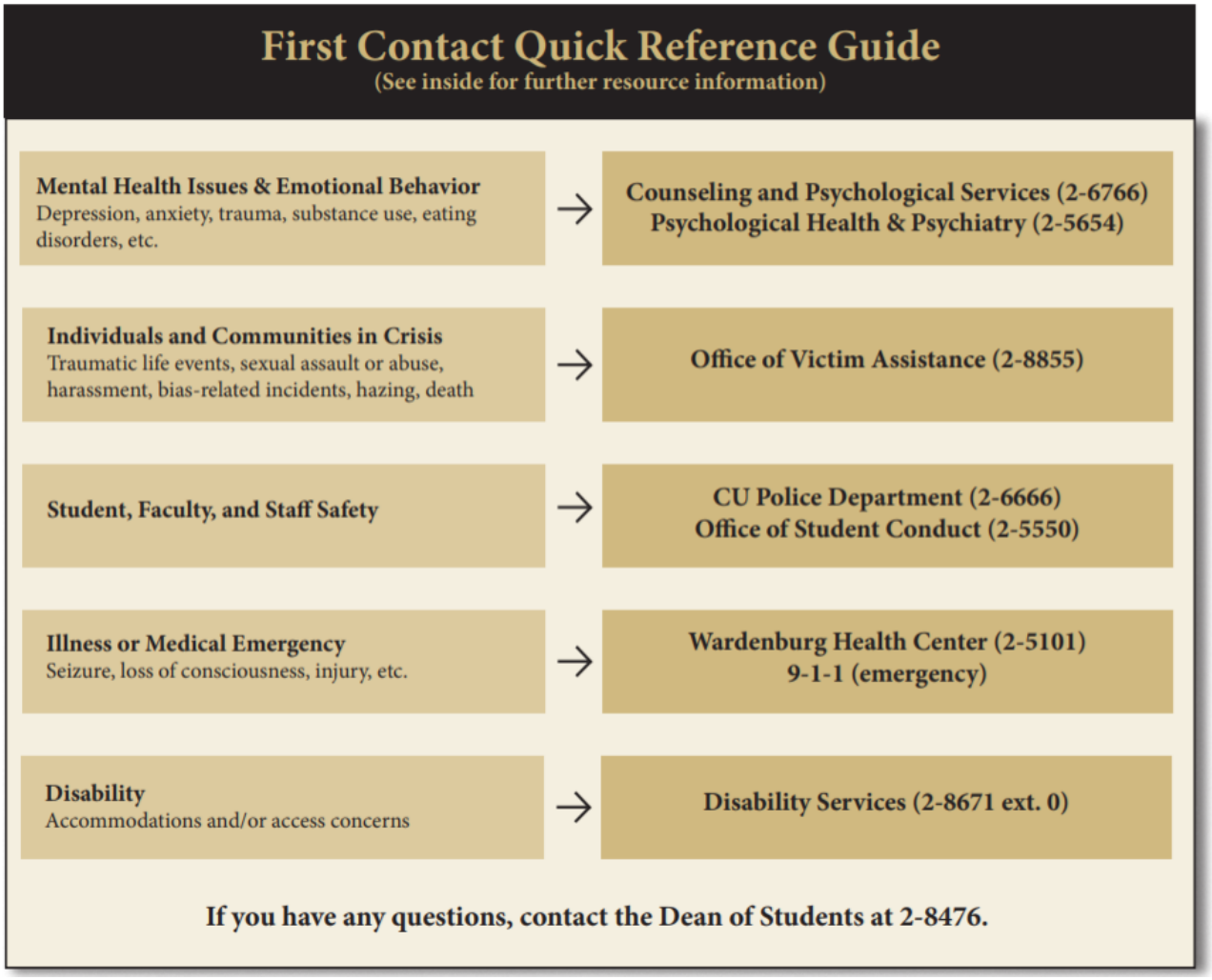
prefer that assignments are returned to students in their student folder in the filing cabinet by the front desk. It is important to organize all assignments by ME ID to make filing more efficient. When filing, the TA may ask the front desk staff if they would be able to help file the assignments only 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*