UCI Samueli School of Engineering | Department of Materials Science and Engineering

# Materials Science and Engineering Graduate Student Handbook

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## Preface

This handbook is intended to help you navigate through your graduate career development, lists useful resources, gives the requirements for each of the M.S. and Ph.D. graduate degrees, and provides guidance on all aspects of your graduate studies. We also encourage you to become active in the department's Graduate Students Association (GSA), as a means of getting to know the other students and become an integral part of the community, to learn from the experiences of those also going through the program, and to have a voice in different aspects of graduate student life. More information on the GSA, including current GSA leadership contact information, is included below. Additionally, a multitude of useful information for your graduate studies can be found here:

https://engineering.uci.edu/current/graduate

## Important Information Regarding COVID-19

Your safety is our top priority. The campus is continuously working on plans, procedures and protocols to help us safely deliver the most effective educational and professional development experience to our students. As the situation is dynamic and rapidly evolving, you are encouraged to frequently monitor the updates on UCI campus responses and safety precautions, changes or modifications to our protocols and procedures, and other relevant information from campus and National health officials, by visiting the following two websites:

UCI Forward:
https://uci.edu/coronavirus/

The CDC COVID-19 Information Portal:
https://www.cdc.gov/coronavirus/2019-ncov/index.html

## Welcome Message from the MSE Graduate Advisor

We would like to welcome you to UC Irvine and to the graduate program in *Materials Science and Engineering*! It is important to note that graduate studies can be stressful. The first year of graduate school may, in particular, seem very challenging and at times overwhelming. However, we are committed to your success, and have an established history of graduating highly successful students and helping them achieve their professional development goals. During their time at UCI, most of these students have found additional resources on campus that have helped them throughout their graduate studies. During your new student orientation, you have been informed of some of these additional resources and support mechanisms. I will remind you that if you feel stressed, at a loss as to how to balance competing demands on your time, or are generally concerned about your mental health, there are free campus resources designed to assist you at the *UCI Counseling Center*: (949) 824-6457. The UCI Graduate Resource Center is another excellent place to find assistance and support for effective professional writing, career planning, or general advice related to your graduate studies and professional development. (https://grad.uci.edu/)

The majority of entering MSE Ph.D. students will have already selected a research advisor after the visitation interviews and subsequent discussions. If you are in the Ph.D. program and have not matched with an advisor, I encourage you to prioritize exploring opportunities and actively engage in further discussions with potential research advisors and use any initial research rotation opportunities wisely to help you decide which research groups and advisors best meet your interests. In cases where projects can benefit from the distinct knowledge and expertise of two different faculty advisors, we strongly encourage students explore having co-advisors.

If you are an international student, we will expect that you will passed the TSE/SPEAK test with a passing score of 50 or higher, or the TOEP test with a score of 5, by the end of the spring quarter of your first year (or have scored 26 or higher on the Speaking portion of the TOEFL iBT). You will have then demonstrated a good command of spoken English and will be eligible for teaching assistant (TA) appointments. TA training is offered each fall, is required for our Ph.D. students, and is mandatory for eligibility for a TA appointment.

Our *Student Services Advisor*, **Desiree Rios**, will be diligently forwarding you important information on things you need to attend to or steps you need to take – both between now and when you arrive on campus, and throughout your graduate studies. Please carefully review these communications and respond accordingly.

You can find additional guidance on steps to complete as an incoming UCI Engineering graduate student at: http://engineering.uci.edu/current/graduate/new-graduate-students

I look forward to your advancement and success as a MSE graduate student, and hope that this handbook and roadmap is helpful in navigating your pathway to your graduate degree.

**Kai He**
Associate Professor and Graduate Advisor, Materials Science and Engineering
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## MSE Departmental Staff and Key Personnel

The main office for the Department of Materials Science and Engineering is in Engineering Tower (ET) 544.
Key personnel for the MSE Graduate Program, and their roles, include:

- ***Professor Lorenzo Valdevit*** *Department Chair* *ET 544*
- ***Professor Kai He*** *MSE Graduate Advisor* *ET 816C*
  - *Primary academic advisor for MSE graduate studies; Provides oversight of, and guidance on, all academic matters including student progress and milestones, coursework and required curriculum, research and research advising, and overall graduate degree requirements, policy and procedures.*
- ***Desiree Rios*** *MSE Student Services Advisor* *ET 544*
  - *Primary contact point for administrative aspects of graduate studies and academic progress; New student onboarding; Coordinator for all graduate paperwork (forms, exam committee and degree program documentation, signatures, exceptions, etc.) and provides oversight of rules, regulations and protocols for graduate programs; Ensures students meet program milestones and timelines/deadlines for academic progress.*
- ***Amy Ricks*** *Chief Administrative Officer* *ET 544*
  - *MSE Department Manager*
- ***Katherine Guerrero*** *Payroll and Personnel Analyst* *ET 544*
  - *Handles all appointments (GSR, TA, etc.) and handles all aspects of employment, fellowship and stipend allocations.*
- ***Viviana Saadalla*** *Administrative Officer* *ET 544*
  - *Front Desk and Business office support; Provides keys for labs, supports conference room reservations and access, and handles mail and package deliveries.*
- ***Darryl Mack*** *Research and Development Engineer* *ET 544*
  - *Laboratory manager and technical support for MSE; oversees teaching labs and departmental research infrastructure.*

## Communication

The faculty, staff and instructors in the Department and School will use email as a **primary means of communication** – and will regularly send important messages to your *UCINetID@***uci.edu** email address. It is *expected* that you are checking this daily (at a minimum)! You must activate your student ID. You should also check (and modify if necessary) your electronic directory listing at UCI to ensure that you are easily contacted and e-mailed by faculty, other students, and university administrative staff.

## Curriculum Requirements and Course Selection

Each of the graduate degree options has a selected set of curricular requirements, including a set of core/required courses. You should familiarize yourself with the *Schedule of Classes* online at UC Irvine (and learn how to explore course offerings from MSE and other campus programs):

https://www.reg.uci.edu/perl/WebSoc

Each quarter, it is recommended that you check MSE listings in the Schedule of Classes and other related disciplines (Chemistry, Physics, CBE, EngrMAE, BME, EECS, etc.) for courses of interest – especially in relation to filling out your elective course requirements.

**Core Courses Required for All MSE Graduate Students –**

The following MSE **core courses** are REQUIRED for **all** new students in MSE graduate degree (M.S. and Ph.D.) programs. Both the Ph.D. preliminary exam and the M.S. comprehensive exam are based, in large part, on materials covered in these required core classes. To remain in good academic standing you must enroll in and complete these core courses in the first year of your studies, in whatever quarter they are offered [note: these courses are offered only once per year].

Currently, we mandate a requirement of **five core courses**, as listed below:

**MSE 200:** *Crystalline Solids: Structure, Properties and Imperfections* (Fall quarter)

**MSE 256A** *Mechanical Behavior of Engineering Materials* (Fall quarter)

**MSE 205** *Materials Physics* (Winter quarter)

**MSE 265A** *Materials Thermodynamics and Statistical Mechanics* (Winter quarter)

**MSE 265B** *Phase Transformations and Kinetic Phenomena in Materials* (Spring quarter)

In addition, all first-year students are REQUIRED to enroll in 6 units (2 units per quarter) of **MSE 298** *Seminars in Engineering* and attend (and participate in) the weekly departmental seminars (Fall, Winter, and Spring quarters).

Every MSE graduate student is assumed to have taken a basic "Introduction to Materials Science and Engineering" undergraduate course prior to enrolling in graduate studies in MSE here at UCI. If you have not taken such a course (e.g., your undergraduate degree was not in MSE and your degree program did not require a broad introductory materials course), you will need to take proactive steps to learn acquire this foundational knowledge. [In this case, you are advised to discuss this with the Graduate Advisor to make plans to either learn the basic principles of MSE through self-study, or possible enroll in a remedial undergraduate course, e.g., **ENGR 54** here at UCI]. The core courses in the MSE graduate program will assume you have an UG-level understanding of the underlying subject matter.

**MSE 200** – provides an understanding of the (atomic/molecular) structure of materials, and covers bonding, short-range and long-range order, key descriptors of crystalline and amorphous structure, the role of defects and imperfections, and connections of these to the properties of materials.

**MSE 256A** – provides a broad-based understanding of the mechanical behavior of engineering materials, and connections to the underlying atomic structure and microstructure.

**MSE 205** – provides a comprehensive understanding of the electronic, optical and dielectric properties of crystalline materials, and imparts a foundational understanding of the underlying physical principles governing the properties of existing or emerging electronic and/or photonic materials.

**MSE 265A** – provides a foundation of advanced thermodynamics and statistical mechanics governing the structure and properties of engineering materials, principles of equilibrium, and the driving forces for materials evolution during processing or application service.

**MSE 265B** – provides a broad-based understanding of kinetics and non-equilibrium behavior of materials, including mass transport and phase transformations.

**Elective Courses for MSE Graduate Students –**

MSE program graduate students are required to take additional graduate courses as technical electives. The specific requirements vary for each of the MSE graduate degree options:

- M.S. students taking the *comprehensive exam* option are required to take 4 additional elective courses (3 units minimum per course) as electives. At least two of these courses must be selected from within the MSE program.
- M.S. students completing the *thesis* option are required to take 4 additional elective courses (3 units minimum per course) as electives, although up to 2 of these elective courses may be substituted by up to 8 units of MSE 296 (M.S. Thesis Research). At least two of these courses must be taken within the MSE program.
- Ph.D. students are required to take a total of 6 additional elective courses (3 units minimum per course). At least three of these courses must be selected from within the MSE program.

**Possibility of Course Waiver –**

We do not waive any MSE core courses regardless of whether you have taken such course(s) elsewhere. However, if you have taken MSE graduate courses elsewhere (perhaps while completing an M.S. degree at another institution), you may be able to petition for waivers for **up to three** individual equivalent **elective** courses in our MSE degree program. However, in such cases, you must seek approval in writing from the Graduate Advisor – *before the start of the quarter that the program graduate elective course is offered* – to receive credit for an equivalent course taken elsewhere (and be exempt from taking that core course during your studies here).

**Suggested Plan of Study –**

The suggested first-year plans, and additional (elective) course requirements, for each of the MSE degree options (M.S. Comprehensive, M.S. Thesis and Ph.D.) are outlined below.

**M.S. Degree – Comprehensive Exam Option:**

Below is the suggested course schedule for the first year of study for students pursuing a M.S. degree via the *Comprehensive Exam* option.

| YEAR 1 | | | |
|---|---|---|---|
| | **FALL** | **WINTER** | **SPRING** |
| Core Courses *(Required)* | MSE 200 (4 units)<br>MSE 256A (4 units) | MSE 265A (4 units)<br>MSE 205 (4 units) | MSE 265B (4 units) |
| MSE Department Seminar (*Required)* | MSE 298 (2 units) | MSE 298 (2 units) | MSE 298 (2 units) |
| Elective Courses | **1** grad elective (≥200 level, 4 units) | **1** grad elective (≥200 level, 4 units) | **2** grad electives (≥200 level, 8 units) |
| **Total Units** | **14** | **14** | **14** |

**M.S. Degree – Thesis Option:**

Below is the suggested course schedule for the first year of study for students pursuing a M.S. degree via the *Thesis* option, wherein a research thesis is completed and defended as detailed below. The only difference in planned curriculum is that two of the elective course requirements may be substituted by research units (after consultation and planning with a research advisor).

| YEAR 1 | | | |
|---|---|---|---|
| | **FALL** | **WINTER** | **SPRING** |
| Core Courses *(Required)* | MSE 200 (4 units)<br>MSE 256A (4 units) | MSE 265A (4 units)<br>MSE 205 (4 units) | MSE 265B (4 units) |
| Research Units (*Required* for M.S. Thesis) | MSE 296 – M.S. thesis units with research advisor (2 units) | MSE 296 (6/2 units, depending on enrollment in elective course) | MSE 296 (10/6 units, depending on enrollment in elective course) |
| MSE Department Seminar (*Required)* | MSE 298 (2 units) | MSE 298 (2 units) | MSE 298 (2 units) |
| Elective Courses | **1** grad elective (≥200 level, 4 units) | **0/1** grad elective (≥200 level, 4 units) | **0/1** grad elective (≥200 level, 4 units) |
| **Total Units** | **16** | **16** | **16** |

**Ph.D. Degree:**

Below is the suggested course schedule for the first two years of study for students pursuing a Ph.D. degree. In the suggested curricular plan that follows, Ph.D. students are *strongly recommended* to take the MSE 201A-B sequence, earning two units in the Fall quarter and two units in the Spring quarter. You must take *both* to earn credit for one elective course.

| **YEAR 1** | | | |
|---|---|---|---|
| | **FALL** | **WINTER** | **SPRING** |
| Core Courses *(Required)* | MSE 200 (4 units)<br>MSE 256A (4 units) | MSE 265A (4 units)<br>MSE 205 (4 units) | MSE 265B (4 units) |
| Research Units (*Required* for Ph.D. Dissertation) | MSE 297 – Ph.D. dissertation units with research advisor (2 units) | MSE 297 (4 units) | MSE 297 (4 units) |
| MSE Department Seminar (*Required)* | MSE 298 (2 units) | MSE 298 (2 units) | MSE 298 (2 units) |
| Elective Courses | **1** grad elective (≥200 level, 4 units) | | **1** grad electives (≥200 level, 4 units) |
| *Highly Recommended Elective Course Sequence for PhD Students* | | **MSE 201A** – Critical Analysis & Technical Communication I (2 units) | **MSE 201B** – Critical Analysis & Technical Communication II (2 units) |
| **Total Units** | **16** | **16** | **16** |

| **YEAR 2** | | | |
|---|---|---|---|
| | **FALL** | **WINTER** | **SPRING** |
| Research Units (*Required* for Ph.D. Dissertation) | MSE 297 (8 units) | MSE 297 (8 units) | MSE 297 (12 units) |
| Elective Courses | **2** grad electives (≥200 level, 8 units) | **2** grad electives (≥200 level, 8 units) | **1** grad elective (≥200 level, 4 units) |
| **Total Units** | **16** | **16** | **16** |

**Research Units –**

Students engaged in academic research should register for MSE 296/297/299 research units, and carefully review expectations for a satisfactory research grade with their faculty research advisor.

If you are a Ph.D. student and have formally matched with a research advisor, you will enroll in **MSE 297**: *Doctor of Philosophy Dissertation Research*. All Ph.D. students **must use** MSE 297 *after* they match with an advisor (by the end of Fall quarter of the first year of study). **Note**: Even if your research faculty advisor has a primary appointment in another department/program, and has a courtesy appointment in MSE, as MSE students, you will enroll in **MSE 297** (under that faculty member's name).

If you are a M.S. student pursuing a *thesis-based* M.S. degree, you will have the opportunity to enroll in **MSE 296**: *Master of Science Thesis Research* units. You should only enroll in MSE 296 after discussing thesis research with a faculty member and mutually agreed upon a research project – and had that faculty member commit to advising M.S. thesis research with you. For the M.S. comprehensive exam (non-thesis) M.S. option, research units do not count toward your degree.

Incoming Ph.D. students who have not yet been formally matched with a research advisor *but have arranged for a research rotation* may enroll in research units under **MSE 299**: *Individual Research*. With the expectation that you have formally matched with a research advisor by the end of the Fall quarter, you should not be enrolling in MSE 299 beyond the first quarter of your studies.

**Departmental Seminar –**

The Department of Materials Science and Engineering runs a MSE departmental seminar series during the academic school year. These seminars, held weekly (typically on Thursday afternoons), provide a unique opportunity to learn about emerging research efforts of scholars from other universities and research institutions, government labs and industry. Regular attendance at departmental seminars is a critical part of your professional development throughout your graduate studies – and including this as a regular part of your weekly calendar is *highly recommended and encouraged*, throughout your time as MSE graduate students.

**All full time MSE graduate students MUST enroll** in MSE 298: *Departmental Seminar* **each quarter** of their first year. You must attend at least 8 out of the 10 seminars per quarter to obtain a passing grade, with attendance taken at the seminars. You are also required to be on time, to stay for the entire seminar, and be respectful of the guest presenter (i.e., be attentive to the seminar). As with any other enrolled course, cheating is academic misconduct and will be addressed as such. In this case, having another individual sign for your attendance, or arriving at the end of the seminar (or leaving early after signing) will result if a failing grade (F) for this course, and possible academic misconduct proceedings.

**Units for Weekly Research Group Meetings –**

Your research advisor may also want you to add one unit of MSE 295: Seminar in Engineering, covering research group meetings. However, these units cannot be used to satisfy elective course requirements for the MSE graduate program. Check with your research advisor.

**Selection of Elective Courses –**

Elective courses are intended to broaden your knowledge in areas relevant to your MSE studies and your research activities (M.S. thesis or Ph.D. dissertation studies). Select elective courses based on discussions with and advice received from your research advisor, to ensure that you have the needed foundational knowledge necessary to advance your research and be competitive within that research group.

Courses numbered 100 – 199 are generally undergraduate upper-division courses. They may be used to satisfy **one** elective course requirement, but only if the course is **NOT** required for the undergraduate MSE degree. In other words, the course must not serve as a remedial course for an existing deficit in UG-level MSE knowledge.

**The MSE Graduate Advisor will distribute a list of pre-approved elective courses each quarter**. These lists are curated after the schedule of classes is posted on the *WebReg Schedule of Classes* (generally shortly before the start of the enrollment period for each quarter), as many of these courses are offered outside of the MSE program; curricular decisions and offerings of these programs (EECS, MAE, CHEM, BME, etc.) are outside of the control of MSE faculty and administrators and often vary from quarter-to-quarter and year-to-year.

If you find a course you wish to take as an elective that is **not on the pre-approved list**, you should contact the MSE Graduate Advisor for approval and verification that the course will count toward the fulfillment of the degree requirements. Again, this should be done after consultation with your research advisor and strategic planning with regards to what is highest impact for advancing your graduate studies.

In considering the use of a select undergraduate course as an elective, be mindful of the fact that many of these courses have formal prerequisites. In the case of Graduate courses (≥ 200 level), the course instructors may have expectations that you have taken other courses prior to the course you are interested in (and treat those courses as "prerequisites"). You are encouraged to contact the instructor of any such proposed elective course for permission to enroll and a discussion to assess whether you will be able to successfully complete the course (with a grade of B or better, so as to not jeopardize your academic standing in the MSE graduate program).

## Graduate Standards for Grading

For graduate students, only the grades of A+, A, A-, B+ B, and S (satisfactory) represent acceptable scholarship, and only coursework in which these grades are received may be applied toward degree requirements. Students must receive a B or higher in a course in order for it to count toward their degree requirements. *An overall grade point average below the B level (3.0/4.0) is not satisfactory*; a student whose grade point average is below that level is subject to Academic Conditional Status (ACS) and potential academic disqualification. The minimum grade point standards noted here also represent minimum requirements for graduate programs in the School of Engineering.

The following should be noted with regards to coursework, grading and cumulative GPA:

- **P/NP Grade Option** – The grade "Pass" (P) is applied to undergraduate coursework only. It is equivalent to a grade of C level work or better and does not meet the standards for satisfactory work in a course for graduate studies. No courses graded "Pass" are to be

included as part of the advanced degree program, nor are they to be considered as satisfying academic criteria for fellowships and academic appointments/employment. If a graduate student chooses the option of P/NP grading, it is assumed that the course is an elective that does not have any significant relationship to the student's progress in the graduate program. A graduate student may elect P/NP grading for one course only (a maximum of 4 units) per quarter. **Under no circumstances will courses taken P/NP count toward unit and degree requirements for any graduate degree program. However, ESL courses can be taken as P/NP and will not count toward degree requirements.**

- **Satisfactory/Unsatisfactory (S/U) Grade Option** – A grade of Satisfactory (S) is equivalent to a grade of B (3.0) or better. No credit is given for a course in which a grade of Unsatisfactory (U) was assigned. You cannot self-elect S/U grading. The S/U grading is assigned by the instructor and may be assigned to all participants in a graduate course. Similarly, individual study and research may be evaluated by means of the grades Satisfactory or Unsatisfactory.

  **NOTE:** When registering, your options listed include "grade" or "P/NP" only. Students taking graduate courses that offer an S/U option, and who wish to elect the S/U option, should select the "grade" option, and then make the necessary arrangements with the instructor. It is at the discretion of each individual faculty member to choose whether to utilize the letter scale (A, B, etc.) or the Satisfactory/Unsatisfactory (S, U) system when assigning grades for research classes.

  It is very important that you discuss this option with your instructor. Do not assume the instructor will remember this option at the end of the quarter. Please make arrangements for S/U grading well before grades are to be assigned. Moreover, grading is at the discretion of the Graduate Adviser, including whether or not to approve your request for S/U grading.

## Academic Standards and Satisfactory Progress

A graduate student is expected to maintain satisfactory progress toward an approved academic objective as defined by the faculty of the MSE program, and in accordance with policies of the Graduate Council and the University. It is important that your academic record be *assessed each quarter* to confirm satisfactory progress. Satisfactory progress is determined on the basis of both your recent academic record and your overall performance. In order to remain in the PhD or MS program, all students must **maintain good academic standing** including the following:

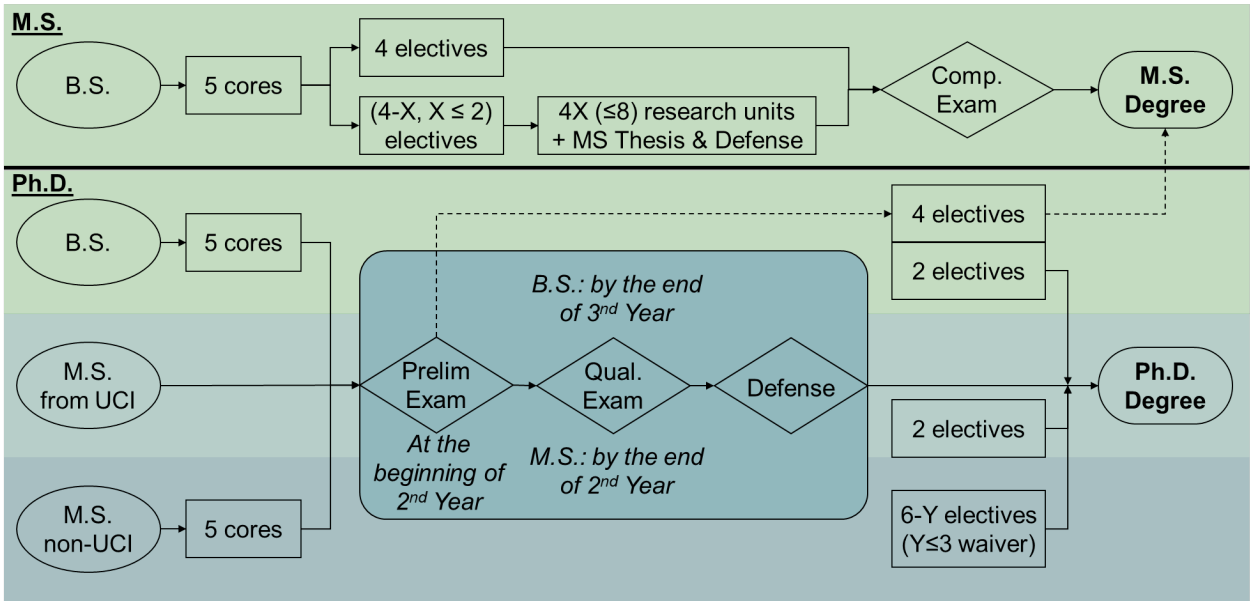
- **GPA –** you must maintain a 3.0 cumulative grade point average. Additionally, a grade of B– or below in any course is considered a non-passing grade.
- **Normative Time to Degree –** the student must advance to candidacy and complete the degree within the limitations established. A student exceeding the maximum time to degree shall be deemed not making satisfactory progress toward their degree; moreover, they shall not receive University resources (e.g., financial aid, TA-ships, housing). The normative time for completion of the Ph.D. is five years (four years for students who entered with a MSE master's degree). The maximum time permitted to complete the Ph.D. is seven years.

- **Grade Reports –** all Incomplete (I), Withdrawal (W), or No Report (NR) grades should be immediately reviewed with the instructor and MSE Graduate Advisor, and appropriate action taken as needed.
- **Enrollment of Units –** students must be enrolled **for at least 12 graduate or upper-division units of credit each quarter**, including credit for supervised teaching and research, unless part-time status or an academic leave of absence has been approved in advance by the Graduate Dean. In cases of approved part-time status, enrollment in eight (8) or fewer units of credit toward the degree is expected each quarter.
- **Distribution of Units –** the number of upper-division and graduate-level units of credit completed toward degree requirements each quarter should be at least 8 units (for part-time) or 12 units (for full time students) and no more than 16 units, unless an exception has been approved.
- **Residency –** time in residence prior to advancement to candidacy for the PhD should be within acceptable limits (ordinarily, no more than four years).

## The Plan of Study Form

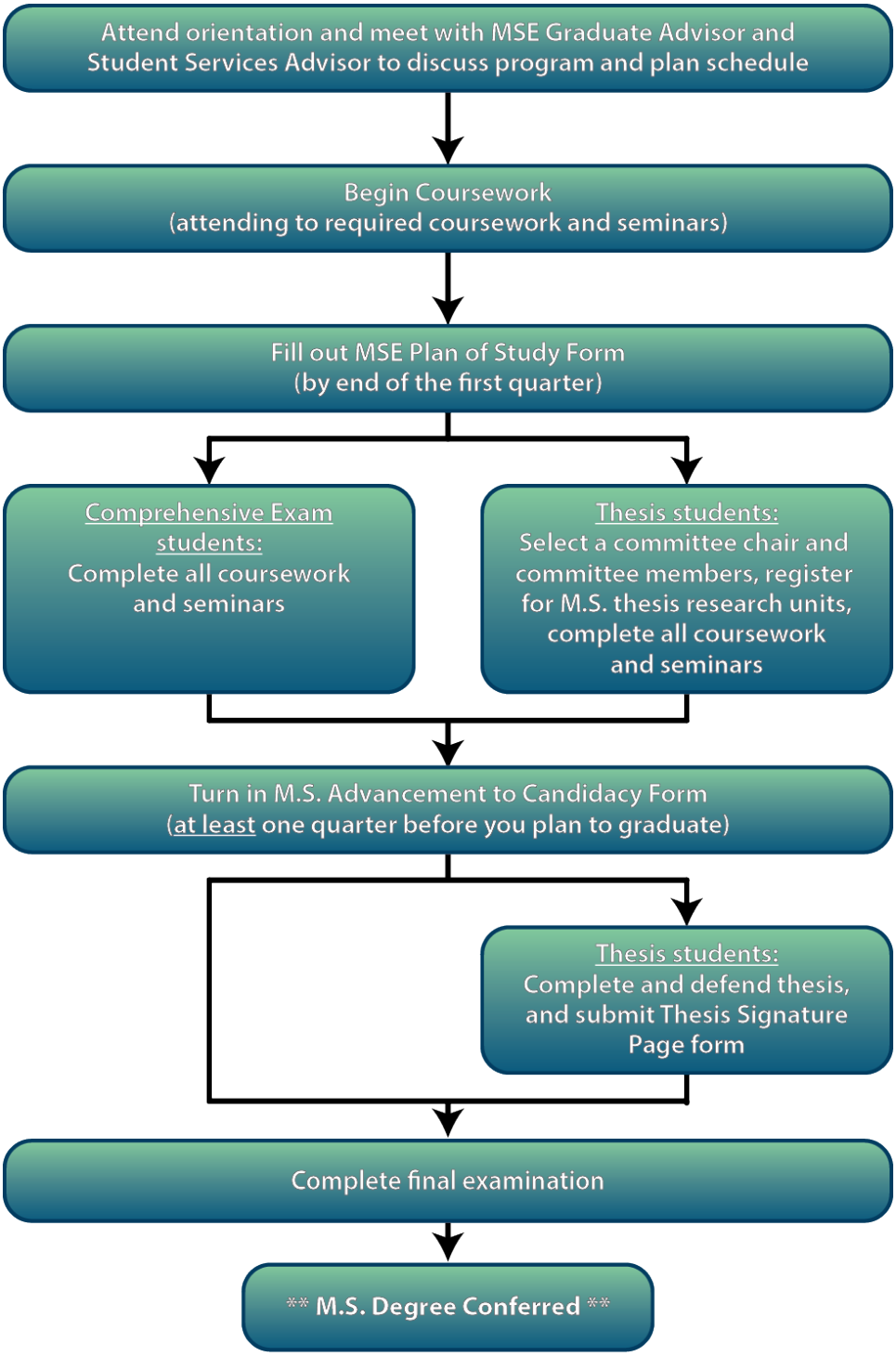
This form documents and codifies the courses that you plan to take to satisfy the curricular components of your graduate degree. You may obtain this form from the Student Services Advisor (Desiree Rios). Completion of this form is **required** for all M.S. and Ph.D. students, *and should be completed by the end of the first quarter of study*. You should submit your completed form to the Student Services Advisor for approval by the Graduate Advisor. You can modify and re-file the form later if your course interests/needs change.

The following flowchart summarizing different paths to MSE M.S. and Ph.D. degrees may help you make a feasible plan of study in your graduate degree program.



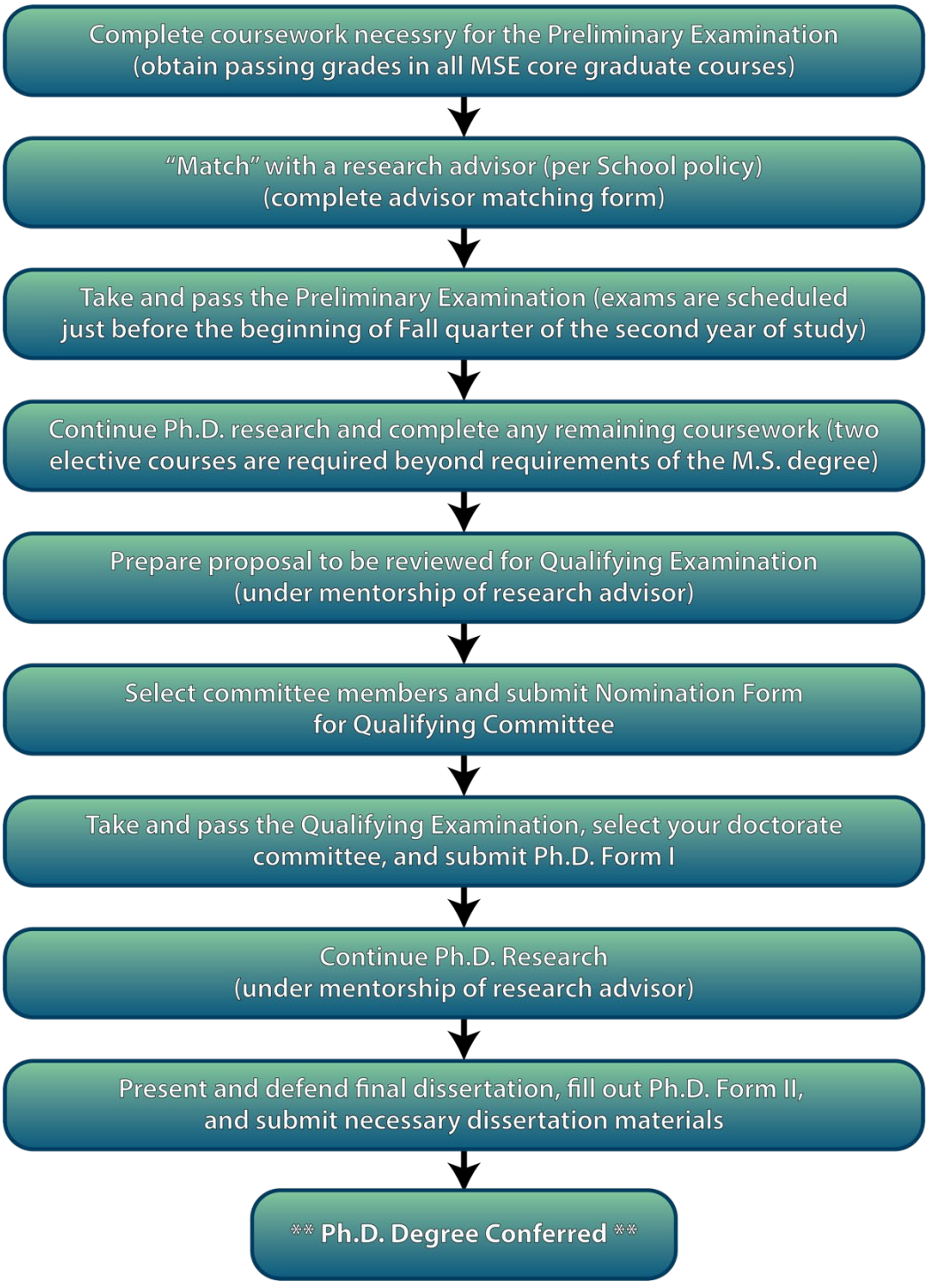
## Milestones Toward MSE Graduate Degree Completion

**Major Steps Toward the M.S. Degree –**



**Major Steps Toward the Ph.D. Degree –**

(If earning a thesis M.S. degree along the way, follow the specific path outlined above including defending the thesis with a thesis committee; otherwise, an M.S. degree is obtained by completing the M.S. comprehensive exam option curriculum requirements outlined above, and subsequently passing the Ph.D. preliminary examination.)



## Materials Science and Engineering Graduate Degree Requirements

A graduate student is expected to maintain satisfactory progress toward an approved academic objective as defined by the faculty of the MSE program, and in accordance with policies of the Graduate Council and the University. It is important that your academic record be *assessed each quarter* to confirm satisfactory progress.

**M.S. Degree Requirements –**

*General Requirements:*

[1] Students must file the Advancement to M.S. Candidacy form **one quarter before** the quarter you intend to graduate. This form must be processed via DocuSign. (Please check with and coordinate with Desiree Rios for preparing and advancing this form for signatures.)

[2] Complete the course requirements (see below for curricular details of the two M.S. degree program options).

[3] Discuss early on with the Graduate Advisor and Student Services Advisor whether the M.S. comprehensive exam option or the M.S. thesis option best suites your interests. Students in the M.S./Ph.D. track may select either the thesis or comprehensive exam (preliminary exam) approach.

**Option 1: M.S. Degree with the Thesis Option**

*This option includes original research with an advisor, a written M.S. thesis and a committee-based thesis defense.*

- Must complete the **five MSE core courses** (described in more detail above).
- Must complete four additional graduate elective courses (3 units minimum/course) numbered 200-289 (or 200-295 if offered by other departments) as approved by the graduate advisor.
- Up to eight units of MSE 296 (M.S. Thesis Research) may be used to substitute for up to two elective courses. One of the elective courses may also be substituted by an upper-division undergraduate elective course, *if approved (prior to enrollment)* by the graduate advisor.
- All full-time students must enroll in the department seminar (as MSE 298), each quarter during their first year. (A total of 3 quarters, or 6 units, are required).
- Must file the Advancement to M.S. Candidacy form at least **one quarter before graduation.**
- Must complete a **M.S. thesis**, approved and defended with a committee of 3 faculty members.
- Must complete the written **M.S. comprehensive exam**. This exam is offered annually in the Spring quarter. Details will be provided to each student during their final quarter of study.
- In addition to fulfilling the course requirements outlined above, it is a University requirement for the Master of Science degree that students fulfill a minimum of 36 units of study.

***General overview: 5 MSE core courses, 2 graduate electives, 8 units of M.S. thesis research, the M.S. thesis (written dossier and oral defense), plus passing the M.S. comprehensive exam => M.S. degree with thesis option.***

**Option 2: M.S. Degree with the Comprehensive Exam Option**

- Must complete the **five MSE core courses** (described in more detail above).
- Must complete four additional graduate elective courses (3 units minimum/course) numbered 200-289 (or 200-295 if offered by other departments) as approved by the graduate advisor.
- All full-time students must enroll in the department seminar (as MSE 298), each quarter during their first year. (A total of 3 quarters, or 6 units, are required).
- Research units do not count toward the requirements of the M.S. degree (comprehensive exam option).
- Must file the Advancement to M.S. Candidacy form at least **one quarter before graduation.**
- Must complete the written **M.S. comprehensive exam**. This exam is offered annually in the Spring quarter. Details will be provided to each student during their final quarter of study.
- In addition to fulfilling the course requirements outlined above, it is a University requirement for the Master of Science degree that students fulfill a minimum of 36 units of study.

***General overview: 5 MSE core courses, 4 graduate electives, plus passing score on the M.S. comprehensive exam => M.S. degree with comprehensive exam option.***

**Switching to the MSE Ph.D. program:** M.S. students who are interested in switching to the Ph.D. program should contact the graduate advisor as soon as possible, to learn about the requirements and explore possibilities. The petition for the change to Ph.D. degree must be filed before the M.S. conferral.

**Ph.D. Degree Requirements –**

All incoming Ph.D. students must register for 2 to 4 units of research (MSE 299). If you have directly matched with an advisor prior to starting your studies, you should register for MSE 297 units under the advisor's course section. Those of you who are not immediately matched with an advisor may temporarily sign up under the Graduate Advisor's name (Professor He) as a placeholder until you have a chance to develop a match with an advisor, at which time you must electronically change (add/drop) to your research advisor's section of MSE 297.

- The initial course requirements are the same as that outlined for the M.S. comprehensive exam option (see above).
- Ph.D. students must take two additional elective courses beyond the M.S. degree requirements. These courses can be taken any time prior to graduation (but are to be taken after the curricular requirements of the M.S. degree are completed). The two courses must be deemed relevant to the student's Ph.D. dissertation topic, be selected in consultation with the research advisor, and be subsequently approved by the MSE Graduate Advisor.
- Ph.D. students must pass the Ph.D. Preliminary Examination during their first year (after the first-year coursework is successfully completed with grades of B or better).

- Ph.D. student must match with a faculty research advisor to guide their doctoral dissertation research, **no later than the end of the Fall quarter of the first year of study** (to remain in good academic standing).
- Also, to remain in good academic standing, an E-IDP (Engineering - Individual Development Plan) form must be completed in consultation with your faculty research advisor(s) and be submitted annually (by July 31st) to the Graduate Advisor and Student Services Advisor. The form will be provided by the Student Services Advisor (Desiree Rios).
- The Ph.D. Qualifying Examination (Advancement to Candidacy) should be completed by the end of the third year of study.
- The final milestone is the preparation of the written Ph.D. dissertation and the oral defense. The dissertation defense must be completed no more than 9 quarters after passing the qualifying (advancement to candidacy) exam or eligibility for financial support may be jeopardized.
- You must work with Desiree Rios to complete the Ph.D. advancement paperwork. The relevant documents must be processed via DocuSign and forwarded for the necessary signatures.
- All students must take a minimum of 12 units per quarter (Fall, Winter and Spring) to be considered full time (and in good academic standing as such). However, we recommend enrolling for 16 units per quarter.

**Means of Support –**

All support for MSE graduate students is given competitively, and requires maintaining good standing in the program. The general means of support are:

- Fellowships (both internal and external). Information on Fellowship opportunities will be provided through orientation sessions and informational emails. In addition, Appendix III below provides links to fellowship opportunities.
- Research Assistantships (GSR), funded from faculty research grants.
- Teaching Assistantships, typically assigned on an ad-hoc basis (and at most once per year).

As U.S. citizens and Permanent Residents must complete the FAFSA form each year, by March 2nd, in order to be eligible for certain financial awards such as GAANN fellowships and federal Work Study awards. See https://studentaid.gov/h/apply-for-aid/fafsa.

**Research Advisors –**

M.S. students taking the comprehensive exam option do not need an advisor other than the MSE graduate advisor. M.S. students interested in pursuing the thesis option should interface with potential research advisors as soon as possible to explore opportunities for research and advising leading to a successful defense of an M.S. thesis. Ph.D. and M.S./Ph.D. students should match with a research advisor (or team of co-advisors) either before the start of the first quarter of study,

or as soon as possible during the first quarter of study. Students having difficulty matching with an advisor should be reach out to the Graduate Advisor as soon as possible for assistance. Ph.D. and M.S./Ph.D. students who are unable to "match" with an advisor by the end of the second quarter of study will no longer remain in academic good standing in the program.

Below is a list of the core MSE faculty, followed by a link where a list of MSE-affiliated faculty may be found. MSE-affiliated faculty can advise MSE graduate students, as approved by the MSE Graduate Advisor and Department Chair.

## MSE Core Faculty

- **Diran Apelian**: *Solidification processing, aluminum metallurgy, clean metal/melt refining, plasma processing / spray forming, powder metallurgy, nanostructured materials, semi-solid processing, thermal processing, resource recovery and recycling, innovation in engineering education.*
- **William Bowman:** *Materials for energy conversion and storage, advanced transmission electron microscopy and spectroscopy, correlating multiscale properties, electrical properties of ceramics, electrochemistry and defect chemistry, interfaces, grain boundaries and surfaces, electron energy-loss spectroscopy, ceramic processing and thin-film growth.*
- **Stacy Copp:** *Soft matter-based photonic materials, metal nanoclusters, polymer nanostructures, self-assembly, biomimetics, machine learning for materials discovery.*
- **Shen Dillon**: *Materials characterization, interface science, in situ microscopy, materials for extreme environments, materials structure-properties relationships in crystalline material.*
- **James Earthman:** *Biomaterials, compositionally complex materials, nanocrystalline alloys, quantitative percussion diagnostics, deformation and damage processes.*
- **Kai He:** *Transmission electron microscopy, spectroscopy, and holography, nanostructured multifunctional materials, clean energy conversion and storage, quantum materials and devices.*
- **Allon Hochbaum**: *Nanoscale materials and hybrid bio-inorganic devices for applications in clean energy.*
- **David Kisailus:** *Investigation of synthesis – structure and structure - property relationships in biological and biomimetic materials, development of multifunctional structural materials, synthesis and crystal growth of nanoscale materials for energy conversion, storage and environmental remediation.*

- **Elizabeth Lee:** *Computational materials and chemistry; quantum, electronic and energy materials; nanoscale transport phenomena; machine learning*.
- **Daniel Mumm**: *Materials for extreme environments, power generation and propulsion systems, inorganics for energy conversion and storage, coatings for thermal/environmental protection, additive manufacturing, materials degradation, and advanced materials characterization via electron microscopy, spectroscopy, and diffraction analysis.*
- **Xiaoqing Pan:** *Atomic-scale structure, properties and dynamic behaviors of advanced materials including thin films and nanostructures for memories, catalysts, and energy conversion and storage devices*.
- **Regina Ragan:** *Exploration and development of novel material systems for nanoscale electronic and optoelectronic devices*.
- **Lorenzo Valdevit:** *Architected materials, mechanical metamaterials, additive manufacturing, optimal design*.

## MSE Affiliated Faculty

For an updated list of MSE-affiliated faculty, please see the department website: https://engineering.uci.edu/dept/mse/faculty-staff/affiliated

## Appendix I:
## MSE M.S. Comprehensive Exam Information and Guidance

**Exam Objectives:**

The M.S. comprehensive exam is meant to assess the breadth and depth of knowledge acquired, and to assess your ability to apply that knowledge to Materials Science and Engineering (MSE) problem solving at a level commensurate with the M.S. degree. This assessment is carried out through an exam covering topics instructed in the five MSE graduate core courses: MSE 200, MSE 205, MSE 256A, MSE 265A, and MSE 265B. The comprehensive exam also serves as the exit exam that is mandated to pass to confer the M.S. degree in MSE.

**Exam Format and Content:**

The exam will be administered in person in a two-hour time slot (specific time and location TBA every year) in the Spring quarter of each academic year. You will be allowed 2 hours to work on the exam. The exam will contain five questions covering topics of the five core courses uniformly (one question from each core course subject matter). There will be a selection of exam content from each topical area (core course subject matter) to allow students to best demonstrate the level of their retained knowledge. The exam will be closed book, while students are allowed to bring their own cheat sheets, calculators, and additional blank pages as needed in your problem solving. During the exam, students are prohibited from accessing course textbooks, course notes, or any other sources of information (online sources, etc.). Doing so would constitute a serious academic misconduct infraction.

A list of topics covered in the core courses, and relevant for this exam, are listed below.

**Exam Grading and Overall Assessment:**

The exam has a total of 100 points with 20 points for each of the five questions. To earn a passing score (70/100 points) on the M.S. comprehensive exam, students will be expected to demonstrate a strong working knowledge in at least three of the core course subject areas and at least a minimal working knowledge in the other two subject areas.

**Exam Outcome:**

Students will be informed of the outcome of the exam within one week after the exam.

**M.S. Comprehensive Exam Topics**

1. <u>Materials Structures, Imperfections and Properties</u>
   (MSE 200 – Structure of Materials, Prof. Dan Mumm)
   - Atomic structure, electron orbitals, and quantum numbers (principal, angular, momentum, spin)

- Chemical bonding and characteristics of the different bond types
- The periodic table, trends in bonding, properties of elements, and electronegativity
- Crystalline material structure, and 'building' crystals from the lattice and basis
- Unit cells
- Miller indices and crystallographic directions
- Crystal systems (2D and 3D)
- 2D Bravais nets and 3D Bravais lattices
- Crystallographic computations (distances, angles, and the metric tensor)
- Reciprocal space, reciprocal lattices, the reciprocal metric tensor, and interplanar spacings.
- Symmetry elements and symmetry operations
- Point groups and space groups
- Interpreting the *International Tables of Crystallography*
- X-ray diffraction and the concept of constructive interference (Bragg's Law)
- Atomic scattering factors and structure factor calculations
- Close-packed structures, interstitial sites and interstitial filling of close-packed structures
- Common metallic and ceramic crystal structures

2. Electronic and Optical Properties
   (MSE 205 – Materials Physics, Prof. Stacy Copp)
   - Reciprocal lattice, Brillouin zone
   - Lattice vibrations: heat capacity and thermal conductivity
   - Electrical conductivity, mobility
   - Pauli exclusion principle and Fermi-Dirac distribution
   - Density of states and Fermi energy
   - Free electron Fermi gas - heat capacity and thermal conductivity
   - Electronic band structures in solids
   - Semiconductors: intrinsic/extrinsic, direct/indirect bandgap
   - Temperature dependence of conductivity of metals and semiconductors
   - Thermal transport in metals and insulators, role of defects
   - Semiconductor devices (pn junction, solar cell, MOSFET)
   - Response to electromagnetic waves: dielectrics, metals

3. Mechanical Behavior
   (MAE 259 – Mechanical Behavior of Engineering Materials, Prof. Jim Earthman)
   - Stress, Strain Definitions, Stress-Strain Curves
   - Elastic Deformation
   - Elastic Modulus, Poisson's Ratio
   - Plastic Deformation
   - Slip Planes and Slip Directions
   - Definition of Dislocations
   - Role of Dislocations in Deformation of Crystalline Solids
   - Interaction of Dislocations
   - Impeding the Movement of Dislocations
   - Methods to Detect Dislocations

- Effect of grain size on mechanical properties of metals and ceramics (including properties of nanocrystalline materials)
- Mechanical Behavior of Polymeric Materials
- Relative Values of E, H for metals, ceramics, polymers
- Resilience, Toughness
- Fracture Mechanics
- Stress Intensity Factor
- Fracture Toughness
- Low Temperature Behavior of Materials (Ductile to Brittle Transition)
- High Temperature Behavior of Materials (Creep)
- Fatigue
- Thermally Induced Stresses

4. Thermodynamics and Statistical Mechanics
   (MSE 265A – Materials Thermodynamics and Statistical Mechanics, Prof. Will Bowman)
   - Equilibrium and Entropy: classical thermodynamics and statistical mechanics
   - Combinatorics
   - Energy and the microscopic world: quantum theory and classical approximations
   - Microstates and microstate probabilities
   - Simple lattice models
   - The principle of equal a priori probability
   - Ensemble averages
   - Thermal equilibrium
   - The principle of maximum entropy, The Second Law
   - The fundamental equation of thermodynamics: equilibrium and derivatives of entropy
   - Extensive and intensive forms
   - The First Law
   - Baths as idealized environments
   - Thermodynamic potentials
   - Legendre transformations
   - Maxwell relations
   - Phase equilibrium and stability: conditions for phase equilibrium
   - The Clapeyron Equation
   - Stability and metastability: spinodal and binodal
   - Solutions and mixtures
   - Chemical potential
   - Interfacial tension
   - Phase diagrams

5. Phase Transformation and Kinetics
   (MSE 265B – Phase Transformations and Kinetic Phenomena in Materials, Prof. Shen Dillon)
   - Diffusion: continuum diffusion and atomic mechanisms for lattice diffusion
   - Thermodynamic driving forces
   - Nucleation and growth
   - Grain growth and coarsening
   - Spinodal decomposition and precipitation

- Solidification
- Grain boundaries and interfacial energy
- Martensitic phase transformations

## Appendix II:
## MSE Ph.D. Preliminary Exam Information and Guidance

**Exam Objectives:**
The MSE preliminary examination is a mandatory oral exam offered at the beginning of Fall quarter in a Ph.D. student's 2nd year to test the examinee's competence in fundamental understanding and critical thinking in key MSE areas relevant to the examinee's Ph.D. research.

**Eligibility:**
MSE Ph.D. students who are in academic good standing and have completed all five MSE core courses with a passing score (B and above) are eligible to take the preliminary exam.

**Exam Format:**
The exam will be carried out in **60 min**. A student examinee will present a journal article to the exam committee in 25 min and answer questions asked by the exam committee in 25 min. The exam committee will discuss and assess the exam outcome in 10 min without the examinee's presence.

**Exam Committee:**
MSE core faculty members will participate in the preliminary exams and serve on a number of four-member exam committees every year. All the participating faculty members will cooperate to ensure consistently calibrated assessment for all examinees. Graduate Advisor will coordinate with core faculty members to assemble specific exam committees.

**Selection of Paper:**
The examinee's faculty advisor will select **three research papers** from recent literature (e.g., published within the recent 6 months) that are deemed to be the most appropriate for the objectives of the preliminary exam and submit them to the Graduate Advisor at least three weeks before the exam date. The Graduate Advisor will assign one paper to the examinee two weeks before the exam date.

**Exam Questions:**
Exam committee members are expected to ask questions related to the assigned paper but within the scope of MSE core knowledge areas. **A bank of common questions** covering MSE core areas (see M.S. Comprehensive Exam list of topics) may be used to help ask the examinee meaningful questions related to the assigned paper.

**Exam Preparation:**
Students will be granted **two weeks for preparation** of their preliminary exams, during which they will work on an assigned research paper. Students are expected to prepare for the preliminary exam with their cohorts through the summer seminar series. Faculty advisors should permit students to take time off from their research to study the exam topics. Faculty advisors should not be involved in the exam preparation with their students beyond providing high-level guidance.

**Exam Outcome:**
Exam rubrics will be generated by the MSE Graduate Committee and approved by the MSE core faculty. The rubrics will also be shared with students to help their preparation for the exam. The exam committee will make a conclusion of "Pass" or "Not Pass" (e.g., Score **≥ 70%** to Pass).

## Appendix III:
## MSE Ph.D. Qualifying Exam Information and Guidance

The purpose of the qualifying examination is to demonstrate that the student is capable of conducting independent Ph.D. research and has a viable research plan for the Ph.D. dissertation. PhD faculty advisors provide guidance but do not dictate every step of research and students need to exhibit an ability for independent thinking to pass this exam. Feedback from the qualifying examination committee is very helpful in developing a viable dissertation topic and appropriate experiments.

The MSE Ph.D. qualifying exam committees follow the rules set by the Graduate Council. The student and the research advisor select the qualifying exam committee, with approval of the MSE Graduate Advisor. The committee should primarily be composed of five faculty members familiar with your area of research interest, insofar as that is possible, and three must have their primary appointment in MSE.

Requests for the Qualifying Exam Committee must be submitted two weeks in advance of the date scheduled for the exam, and this form requires multiple signatures, including the Associate Dean's. Current guidelines require five committee members with at least three faculty from MSE. Outside member who is not a member or joint appointee of the MSE department may serve the exam committee but is not required.

For more information, check the Office of Graduate Studies website for the most current information. http://www.grad.uci.edu/forms/

Normally, three members of the Qualifying Exam Committee will form your dissertation committee.

The Ph.D. Qualifying Examination should be scheduled between the beginning of the 3rd year and the beginning of the 4th year. If not completed by the end of the 3rd year, the student in conjunction with their faculty advisor must submit a plan with milestones for completing this exam in a timely manner. If the qualifying examination is not taken by the end of Winter quarter of the 4th year, the student is no longer in good academic standing and may not be eligible for financial support. After completion of this exam, the student is considered Advanced to Candidacy for the Ph.D.

There are two required parts of the qualifying examination:

I. Written Dossier
II. Oral Presentation (30-35 minutes)

The written dossier must be approved and signed off on the title page by the advisor before the dossier is distributed to the committee members and before the qualifying examination can be scheduled. You can schedule the exam before the dossier is complete, but it should be distributed to the other 4 committee members a week in advance of the exam (and must have advisor signature on front, indicating approval for distribution).

## I. Written Research Summary (Dossier)

Use Times New Roman 12 font, 1.5 line spacing or equivalent. Pages are approximations.

| | |
|---|---|
| 1 page | 1) Title Page – Title, Name of Student, Degree Program, Date, Advisor and Advisor's Signature |
| 1 page | 2) Abstract Page – 100-word summary – include the new information obtained from experiments and/or theory/ new understanding provided to the research field/ major contribution that the dissertation will provide to the research community. |
| 1 page | 3) Introduction – brief discussion of current state of knowledge in the research field, rationale for research and how it adds to current knowledge, scientific content impact of research in technology and society, what key questions will be answered. |
| 2-3 pages | 4) Background – Extensive discussion of prior research relevant to your research should be discussed to demonstrate a knowledge of the current state of the field and the rationale for challenges addressed by your research. |
| 3-5 pages | 5) Preliminary Results – a summary of your work to date, including research methods and interpretation of data obtained by the P.D. candidate. Include figures, graphs, and tables and the development of any models. Explain the science and technology associated with the data. |
| 2-4 pages | 6) Future Research Plan – a thorough discussion of the experiments the student plans to complete for his/her thesis. Explain how the experiments will provide critical information for the dissertation and define significant contributions to the research field. |
| 1 page | 7) Timeline – Provide an estimated timeline of when you will complete experiments, analysis, paper writing, and thesis document. |
| 1 page | 8) Summary – Summarize the new fundamental and technological research contributions that are expected from this proposed research |
| x pages | 9) References – Author name/s, full title, journal, volume, page, year |

The dossier, *excluding* References but including Figures and Tables will probably be about 15 – 25 pages. It is appropriate to change the research plan as experiments evolve, but the research plan presented in the qualifying examination serves to document the general expectations for the Ph.D.

This document can serve as a draft for the introductory chapters of the Ph.D. This document will serve as an outline for the Ph.D. dissertation, and you will save time later when writing the dissertation if you complete this properly. The introduction and background provide a good draft for the first chapter of the dissertation (with an update of the research field a few years later), and the preliminary experiments should be a draft of one chapter for the dissertation.

## II. **Oral Examination**

During the oral examination the student should summarize the written document with less emphasis on published research by others than on the preliminary and future work of the examinee. This will be a PowerPoint presentation about 30-40 minutes in length. The five faculty members on the committee will question the student and offer suggestions for the Ph.D. dissertation. At least two hours should be scheduled in order to allow time for questions.

At this exam, examiners may return the Research Dossier with written suggestions in the text. The purpose of the oral exam is to evaluate the student's understanding of the proposed research and his/her ability to conduct original, independent research.

## Appendix IV:
## Graduate Program Learning Outcomes

(MS in Materials Science and Engineering)

### I. Program Learning Outcomes

**Core Knowledge**. Students will be able to:

- Demonstrate general knowledge of core topics and theory in Materials Science and Engineering necessary for professional practice or PhD studies.

**Research Methods and Analysis**. Students will be able to:

- Understand the qualitative and quantitative methodologies typically used in Materials Science and Engineering practice and research.
- Demonstrate the ability to critically analyze research literature.

**Professionalism**. Students will:

- Participate in seminar series presented by professionals and academicians in Materials Science and Engineering and Materials Science and Engineering.

### II. Assessment Plan

| PLO | Direct | Indirect |
|---|---|---|
| Core Knowledge | -GPA≥3.0 in MSE core courses<br>-MS Comp. exam | Exit interview / Survey |
| Research Methods and Analysis | -MS Thesis<br>- Independent Study<br>-MS comp. exam | Exit interview / Survey |
| Professionalism | -Participation in Seminar Series | Exit interview / Survey |

### III. Action Plan Timeline

PLOs are assessed at the time graduation for each student. Data are compiled annually and used for continuous improvement of the graduate program.

(PhD in Materials Science and Engineering)

## I. Program Learning Outcomes

**Core Knowledge**. Students will be able to:

- Demonstrate general knowledge of core topics and theory in Materials Science and Engineering necessary for professional practice and/or academic research.

**Pedagogy**. Students will be able to:

- Communicate effectively to large and small groups in pedagogical settings in lecture and/or discussion formats.

**Scholarly Communication**. Students will be able to:

- Structure a coherent academic argument that rigorously presents and evaluates research data.
- Make clear and cogent presentations, and professional documents that summarize their research and its significance.

**Independent Research**. Students will be able to:

- Develop and carry out independent research projects with theoretical and methodological rigor.

**Broader Impacts**. Students will be able to:

- Understand the technological and societal impacts of their research.

| PLO | Direct | Indirect |
|---|---|---|
| Core Knowledge | -GPA≥3.0 in MSE core courses<br>-Preliminary Exam | Exit interview / Survey |
| Pedagogy | -Teaching Assistantship or Tutorial Seminar | Exit interview / Survey |
| Scholarly Communication | -Research Paper<br>- Conference Presentations<br>- PhD Defense | Exit interview / Survey |
| Independent Research | -Qualifying Exam<br>-PhD Dissertation | Exit interview / Survey |
| Broader Impacts | -Qualifying Exam<br>-PhD Dissertation | Exit interview / Survey |

## II. Assessment Plan

**III. Action Plan Timeline**

PLOs are assessed at the time of graduation for each student. Data are compiled annually and used for continuous improvement of the graduate program.

## Appendix V: External Fellowship Opportunities

Current and prospective graduate students are encouraged to apply for external fellowships that they are eligible for. In addition to the list below, many governments and corporations award fellowships.

National Science Foundation Graduate Research Fellowship Program
http://www.nsfgrfp.org/

National Defense Science and Engineering Graduate Fellowship
https://ndseg.sysplus.com/

SMART Fellowship
https://www.smartscholarship.org/smart

DoE Office of Science Graduate Student Research Program
https://science.osti.gov/wdts/scgsr

DoE Computational Science Graduate Fellowship
http://www.krellinst.org/csgf/

Hertz Foundation Graduate Fellowship
http://www.hertzfoundation.org/

Graduate Fellowships for STEM Diversity
https://stemfellowships.org/

Fulbright Program
http://us.fulbrightonline.org/home.html

## Appendix VI: Suggested Supplementary Reading

Current and prospective graduate students are encouraged to read or review the following, to better understand the process and expectations of pursuing an advanced degree in STEM fields.

Good Grad! A Practical Guide to Graduate School in the Sciences and Engineering
J.W. Gangestad (2013)

Survival Skills for Scientists
F. Rosei and T. Johnston (2006)

The Ph.D. Process – A Student's Guide to Graduate School in the Sciences
D.F. Bllom, J.D. Karp and N. Cohen (1998)