MATERIALS SCIENCE AND ENGINEERING

Courses offered by the Department of Materials Science and Engineering are listed under the subject code MATSCI on the *Stanford Bulletin's* ExploreCourses (http://explorecourses.stanford.edu/browse/) web site.

The Department of Materials Science and Engineering is concerned with the relation between the structure and properties of materials, factors that control the internal structure of solids, and processes for altering their structure and properties, particularly at the nanoscale.

Mission of the Undergraduate Program in Materials Science and Engineering

The mission of the undergraduate program in Materials Science and Engineering is to provide students with a strong foundation in materials science and engineering with emphasis on the fundamental scientific and engineering principles which underlie the knowledge and implementation of material structure, processing, properties, and performance of all classes of materials used in engineering systems. Courses in the program develop students' knowledge of modern materials science and engineering, teach them to apply this knowledge analytically to create effective and novel solutions to practical problems, and develop their communication skills and ability to work collaboratively. The program prepares students for careers in industry and for further study in graduate school.

The B.S. in Materials Science and Engineering provides training for the materials engineer and also preparatory training for graduate work in materials science. Capable undergraduates are encouraged to take at least one year of graduate study to extend their course work through the coterminal degree program which leads to an M.S. in Materials Science and Engineering. Coterminal degree programs are encouraged both for undergraduate majors in Materials Science and Engineering and for undergraduate majors in related disciplines.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. Students are expected to demonstrate the ability to:

1. Apply the knowledge of mathematics, science, and engineering to assess and synthesize scientific evidence, concepts, theories, and experimental data relating to the natural or physical world.
2. Extend students' knowledge of the natural or physical world beyond that obtained from secondary education by refining their powers of scientific observation, the essential process by which data is gained for subsequent analysis.
3. Design and conduct experiments, as well as understand and utilize the scientific method in formulating hypotheses and designing experiments to test hypotheses.
4. Function on multidisciplinary teams, while communicating effectively.
5. Identify, formulate, and solve engineering issues by applying conceptual thinking to solve certain problems, bypassing calculations or rote learning and relying on the fundamental meaning behind laws of nature.
6. Understand professional and ethical responsibility.
7. Understand the impact of engineering solutions in a global, economic, environmental, and societal context.
8. Demonstrate a working knowledge of contemporary issues.
9. Recognize the need for, and engage in, lifelong learning.
10. Apply the techniques, skills, and modern engineering tools necessary for engineering practice.
11. Transition from engineering concepts and theory to real engineering applications and understanding the distinction between scientific evidence and theory, inductive and deductive reasoning, and understanding the role of each in scientific inquiry.

Graduate Programs in Materials Science Engineering

Graduate programs lead to the degrees of Master of Science, Engineer, and Doctor of Philosophy. Graduate students can specialize in any of the areas of materials science and engineering.

Learning Outcomes (Graduate)

The purpose of the master's program is to provide students with the knowledge and skills necessary for a professional career or doctoral studies. This is done through course and laboratory work in solid state fundamentals and materials engineering, and further course work in a technical depth area which may include a master's Research Report. Typical depth areas include nanocharacterization, electronic and photonic materials, energy materials, nano and biomaterials.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research. Through course work and guided research, the program prepares students to make original contributions in Materials Science and Engineering and related fields.

Facilities

The department is located in the William F. Durand Building, with extensive facilities in the Jack A. McCullough Building and the Gordon and Betty Moore Materials Research Building. These buildings house offices for the chair, majority of the faculty, administrative and technical staff, graduate students as well as lecture and seminar rooms. The research facilities are equipped to conduct electrical measurements, mechanical testing of bulk and thin film materials, fracture and fatigue of advanced materials, metallography, optical, scanning, transmission electron microscopy, atomic force microscopy, UHV sputter deposition, vacuum annealing treatments, wet chemistry, and x-ray diffraction.

The McCullough/Moore Complex is also the home for the Center for Magnetic Nanotechnology (CMN (https://nanomag.stanford.edu/)), Stanford Nanocharacterization Laboratory (SNL) and Nanoscale Prototyping Laboratory (NPL (http://npl-web.stanford.edu/); joint facility with Mechanical Engineering in Building 530).

Depending on the needs of their programs, students and faculty also conduct research in a number of other departments and independent laboratories. Chief among these are the Stanford Nanofabrication Facility (SNF (http://snf.stanford.edu/)), Geballe Laboratory for Advanced Materials (GLAM (http://stanford.edu/group/glam/)), and Stanford Synchrotron Radiation Laboratory (SSRL (http://www-ssrl.slac.stanford.edu/)).

The Stanford Nanofabrication Facility (SNF) is a laboratory joining government and industrially funded research on microelectronic materials, devices, and systems. It houses a 10,000 sq. ft., class 100 clean room for Si and GaAs integrated circuit fabrication, a large number of electronic test, materials analysis, and computer facilities, and office space for faculty, staff, and students. In addition, the Center for Integrated Systems (CIS (http://cis.stanford.edu/)) provides start-up research funds and maintains a fellow-mentor program with industry.

Bachelor of Science in Materials Science and Engineering (MSE/MATSCI)

Completion of the undergraduate program in Materials Science and Engineering leads to the conferral of the Bachelor of Science in Materials Science and Engineering.

Mission of the Undergraduate Program in Materials Science and Engineering

The mission of the undergraduate program in Materials Science and Engineering is to provide students with a strong foundation in materials science and engineering with emphasis on the fundamental scientific and engineering principles which underlie the knowledge and implementation of material structure, processing, properties, and performance of all classes of materials used in engineering systems. Courses in the program develop students' knowledge of modern materials science and engineering, teach them to apply this knowledge analytically to create effective and novel solutions to practical problems, and develop their communication skills and ability to work collaboratively. The program prepares students for careers in industry and for further study in graduate school.

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3. Design and conduct experiments, as well as understand and utilize the scientific method in formulating hypotheses and designing experiments to test hypotheses.
4. Function on multidisciplinary teams, while communicating effectively.
5. Identify, formulate, and solve engineering issues by applying conceptual thinking to solve certain problems, bypassing calculations or rote learning and relying on the fundamental meaning behind laws of nature.
6. Understand professional and ethical responsibility.
7. Understand the impact of engineering solutions in a global, economic, environmental, and societal context.
8. Demonstrate a working knowledge of contemporary issues.
9. Recognize the need for, and engage in, lifelong learning.
10. Apply the techniques, skills, and modern engineering tools necessary for engineering practice.
11. Transition from engineering concepts and theory to real engineering applications and understanding the distinction between scientific evidence and theory, inductive and deductive reasoning, and understanding the role of each in scientific inquiry.

Degree Requirements

		Units
Mathematics		
20 units minimum		
Select one of the following:		5
MATH 51	Linear Algebra, Multivariable Calculus, and Modern Applications	
CME 100/ ENGR 154	Vector Calculus for Engineers	
Select one of the following:		5
MATH 52	Integral Calculus of Several Variables	
CME 104/ ENGR 155B	Linear Algebra and Partial Differential Equations for Engineers	
Select one of the following:		5
MATH 53	Ordinary Differential Equations with Linear Algebra	
CME 102/ ENGR 155A	Ordinary Differential Equations for Engineers	
One additional course [1]		5
Science		
20 units minimum		
Must include a full year (15 units) of calculus-based physics or chemistry, with one quarter of study (5 units) in the other subject. [2]		20
Technology in Society		
One course minimum [3]		3-5
Engineering Fundamentals		
Two courses minimum		
Select one of the following:		4
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis [4]	
ENGR 50E	Introduction to Materials Science, Energy Emphasis [4]	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis [4]	
At least one additional courses [4]		3-5
Department Requirements: MSE Fundamentals, Depth & Focus Areas		
Materials Science Fundamentals: All of the following courses:		16
MATSCI 142	Quantum Mechanics of Nanoscale Materials	
MATSCI 143	Materials Structure and Characterization	
MATSCI 144	Thermodynamic Evaluation of Green Energy Technologies	
MATSCI 145	Kinetics of Materials Synthesis	
Two of the following courses:		8
MATSCI 151	Microstructure and Mechanical Properties	
MATSCI 152	Electronic Materials Engineering	
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	
MATSCI 158	Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life	
MATSCI 190	Organic and Biological Materials	
MATSCI 192	Materials Chemistry	
MATSCI 193	Atomic Arrangements in Solids	
MATSCI 194	Thermodynamics and Phase Equilibria	

MATSCI 195	Waves and Diffraction in Solids	
MATSCI 196	Defects in Crystalline Solids	
MATSCI 197	Rate Processes in Materials	
MATSCI 198	Mechanical Properties of Materials	
MATSCI 199	Electronic and Optical Properties of Solids	
Materials Science & Engineering Depth		**16**
Four laboratory courses for Sixteen units; Four units must be WIM		
MATSCI 160	Nanomaterials Laboratory	
MATSCI 161	Energy Materials Laboratory (WIM)	
MATSCI 162	X-Ray Diffraction Laboratory	
MATSCI 163	Mechanical Behavior Laboratory	
MATSCI 164	Electronic and Photonic Materials and Devices Laboratory (WIM)	
MATSCI 165	Nanoscale Materials Physics Computation Laboratory	
MATSCI 166	Data Science and Machine Learning Approaches in Chemical and Materials Engineering	
Focus Area Options [5, 6]		13
Total Units		103-107

[1] See a list of approved math courses at ughb.stanford.edu (https://ughb.stanford.edu/courses-and-planning/approved-courses/). AP/IB Credit (https://ughb.stanford.edu/petitions/ap-credit/) may also be used to meet the 20 units minimum, but cannot replace the three required courses.

[2] See a list of approved science courses at ughb.stanford.edu (https://ughb.stanford.edu/courses-and-planning/approved-courses/). AP/IB Credit (https://ughb.stanford.edu/petitions/ap-credit/)may also be used to meet the 20 units minimum in some cases; see the AP chart in the Bulletin or check with the School of Engineering in 135 Huang Engineering Center.

[3] See a list of approved Technology in Society courses at ughb.stanford.edu (https://ughb.stanford.edu/courses-and-planning/approved-courses/). Course chosen must be on the approved list the year taken.

[4] See a list of approved Engineering Fundamentals Courses at ugh.stanford.edu. Course chosen must be on the approved list the year taken.

[5] Focus Area Options: 13 units from one of the following Focus Area Options below. If the focus area contains only 12 units, but the combined unit total in major (SoE Fundamentals, MSE Fundamentals, MSE Depth and the Focus Area) is at 60 or more, it will be allowed and no petition is necessary.

[6] The self-defined focus area option requires additional approval; program deviation forms for this option can be found on the MSE website (https://mse.stanford.edu/student-resources/forms/undergraduate/).

[7] A course may only be counted towards one requirement; it may not be double-counted. For the 2020-2021 academic year, all courses taken for the major may be taken for either a letter grade (if offered by the instructor) or for CR and count towards degree requirements. Minimum Combined GPA for all courses in Engineering Topics (Engineering Fundamentals and Depth courses) is 2.0.

Focus Area Options (Four courses for a minimum of 13 units; select from one of the ten Focus Areas.)

Bioengineering	
BIOE 80	Introduction to Bioengineering (Engineering Living Matter)
BIOE 220	Introduction to Imaging and Image-based Human Anatomy
BIOE 260	Tissue Engineering
BIOE 281	Biomechanics of Movement
BIOE 381	Orthopaedic Bioengineering
MATSCI 158	Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life
MATSCI 190	Organic and Biological Materials
MATSCI 225	Biochips and Medical Imaging
MATSCI 380	Nano-Biotechnology
MATSCI 381	Biomaterials in Regenerative Medicine
MATSCI 384	Materials Advances for Neurotechnology: Materials Meet the Mind
Chemical Engineering	
CHEM 171	Foundations of Physical Chemistry
CHEMENG 130	
CHEMENG 140	Micro and Nanoscale Fabrication Engineering
CHEMENG 150	Biochemical Engineering
MATSCI 158	Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life
Chemistry	
CHEM 151	Inorganic Chemistry I
CHEM 153	Inorganic Chemistry II
CHEM 171	Foundations of Physical Chemistry
CHEM 173	Physical Chemistry II
CHEM 175	Physical Chemistry III
CHEM 181	Biochemistry I
CHEM 183	Biochemistry II
CHEM 185	Biophysical Chemistry
Electronics & Photonics	
EE 101A	Circuits I
EE 101B	Circuits II
EE 102A	Signal Processing and Linear Systems I
EE 102B	Signal Processing and Linear Systems II
EE 116	Semiconductor Devices for Energy and Electronics
EE 134	Introduction to Photonics
EE 142	Engineering Electromagnetics (Formerly EE 141)
EE 155	Green Electronics
ME 210	Introduction to Mechatronics
MATSCI 343	Organic Semiconductors for Electronics and Photonics
MATSCI 346	Nanophotonics
Energy Technology	
EE 293B	Fundamentals of Energy Processes
EE 155	Green Electronics
CEE 107A	Understanding Energy
EE 293B	Fundamentals of Energy Processes
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution
MATSCI 302	Solar Cells
MATSCI 303	Principles, Materials and Devices of Batteries
ME 262	Physics of Wind Energy
Materials Characterization Techniques	
MATSCI 320	Nanocharacterization of Materials

MATSCI 321	Transmission Electron Microscopy
MATSCI 322	Transmission Electron Microscopy Laboratory
MATSCI 323	Thin Film and Interface Microanalysis
MATSCI 326	X-Ray Science and Techniques
CHEMENG 345	Fundamentals and Applications of Spectroscopy
BIO 232	Advanced Imaging Lab in Biophysics
APPPHYS 201	Electrons and Photons (PHOTON 201)
Mechanical Behavior & Design	
AA 240	Analysis of Structures
AA 256	Mechanics of Composites
MATSCI 198	Mechanical Properties of Materials
MATSCI 241	Mechanical Behavior of Nanomaterials
MATSCI 358	Fracture and Fatigue of Materials and Thin Film Structures
ME 80	Mechanics of Materials
or CEE 101A	Mechanics of Materials
ME 203	Design and Manufacturing
Nanoscience	
ENGR 240	Introduction to Micro and Nano Electromechanical Systems
MATSCI 241	Mechanical Behavior of Nanomaterials
MATSCI 316	Nanoscale Science, Engineering, and Technology
MATSCI 320	Nanocharacterization of Materials
MATSCI 346	Nanophotonics
MATSCI 347	Magnetic materials in nanotechnology, sensing, and energy
MATSCI 380	Nano-Biotechnology
Physics	
PHYSICS 70	Foundations of Modern Physics
PHYSICS 110	Advanced Mechanics
PHYSICS 120	Intermediate Electricity and Magnetism I
PHYSICS 121	Intermediate Electricity and Magnetism II
PHYSICS 130	Quantum Mechanics I
PHYSICS 131	Quantum Mechanics II
PHYSICS 134	Advanced Topics in Quantum Mechanics
PHYSICS 170	Thermodynamics, Kinetic Theory, and Statistical Mechanics I
PHYSICS 171	Thermodynamics, Kinetic Theory, and Statistical Mechanics II
PHYSICS 172	Solid State Physics
Self-Defined Option	
Petition for a self-defined cohesive program. [7]	

For additional information and sample, programs see the Handbook for Undergraduate Engineering Programs (http://ughb.stanford.edu).

Honors Program

The Materials Science and Engineering honors program offers an opportunity for undergraduate Materials Science and Engineering majors with a GPA of 3.5 or higher to pursue independent research at an advanced level, supported by a faculty advisor and graduate student mentors. The main requirements are as follows:

1. Application to the honors program (must be pre-approved by faculty advisor)
2. Enrollment in MATSCI 150 Undergraduate Research and participation in an independent research project over three sequential full quarters
3. Completion of a faculty-approved thesis
4. Participation in either a poster or oral presentation of thesis work at a Stanford Symposium/event or, at your faculty advisor’s discretion, in a comparable public event.

Since this requires three full quarters of research in addition to a final written thesis and presentation following completion of the work, students must apply to the program no less than four quarters prior to their planned graduation date. Materials Science and Engineering majors pursuing a typical four-year graduation timeline should meet with student services no later than the Winter Quarter of their junior year to receive information on the application process.

All requirements for the honors program are in addition to the normal undergraduate program requirements.

To apply to the MATSCI Honors program

- Have an overall GPA of 3.5 or higher (as calculated on the unofficial transcript) prior to application.
- Seek out a faculty research advisor and agree on a proposed research topic. If the research advisor is not a member of the MSE faculty or not a member of the School of Engineering Academic Council, students must have a second advisor who fulfills these requirements.
- Compose a brief (less than 1 page) summary of proposed research, including a proposed title, and submit along with unofficial transcript and signed application/faculty endorsement (https://mse.stanford.edu/student-resources/forms/undergraduate/).
- Submit application to MATSCI student services (Durand 113) at least four quarters prior to planned graduation.

To complete the MATSCI Honors program

- Overall GPA of 3.5 or higher (as calculated on the unofficial transcript) at graduation.
- Complete at least three quarters of research with a minimum of 9 units of MATSCI 150 (students may petition out of unit requirement with faculty adviser approval). All quarters must focus on the same topic. Maintain the same faculty adviser throughout, if possible.
- Present either a poster or oral presentation of thesis work at a Stanford event or, at the faculty advisor’s discretion, in a comparable public event.
- Submit final drafts of an honors thesis to two faculty readers (one must be your research advisor, and one must be an MSE faculty member/SoE Academic Council member) at least one quarter prior to graduation. Both must approve the thesis by completing the signature page (https://mse.stanford.edu/student-resources/forms/undergraduate/).
- Submit to MATSCI student services (Durand 113) one copy of the honors thesis and signed signature page (in electronic or physical form) at least one quarter prior to graduation.

Materials Science and Engineering (MATSCI) Minor

A minor in Materials Science and Engineering allows interested students to explore the role of materials in modern technology and to gain an understanding of the fundamental processes that govern materials behavior.

The following courses fulfill the minor requirements:

		Units
Engineering Fundamentals		
Select one of the following:		4
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	

ENGR 50E	Introduction to Materials Science, Energy Emphasis	
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	
Materials Science Fundamentals and Engineering Depth		
Select six of the following:		24
MATSCI 142	Quantum Mechanics of Nanoscale Materials	
MATSCI 143	Materials Structure and Characterization	
MATSCI 144	Thermodynamic Evaluation of Green Energy Technologies	
MATSCI 145	Kinetics of Materials Synthesis	
MATSCI 151	Microstructure and Mechanical Properties	
MATSCI 152	Electronic Materials Engineering	
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	
MATSCI 158	Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life	
MATSCI 160	Nanomaterials Laboratory	
MATSCI 161	Energy Materials Laboratory	
MATSCI 162	X-Ray Diffraction Laboratory	
MATSCI 163	Mechanical Behavior Laboratory	
MATSCI 164	Electronic and Photonic Materials and Devices Laboratory	
MATSCI 165	Nanoscale Materials Physics Computation Laboratory	
MATSCI 190	Organic and Biological Materials	
MATSCI 192	Materials Chemistry	
MATSCI 193	Atomic Arrangements in Solids	
MATSCI 194	Thermodynamics and Phase Equilibria	
MATSCI 195	Waves and Diffraction in Solids	
MATSCI 196	Defects in Crystalline Solids	
MATSCI 197	Rate Processes in Materials	
MATSCI 198	Mechanical Properties of Materials	
MATSCI 199	Electronic and Optical Properties of Solids	
Total Units		28

Master of Science in Materials Science Engineering

The University's basic requirements for the M.S. degree are discussed in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/)" section of this bulletin. The following are specific departmental requirements.

The Department of Materials Science and Engineering requires a minimum of 45 units for a master's degree to be taken in residence at Stanford. A Master's Program Proposal (https://mse.stanford.edu/student-resources/forms/masters/) form should be filled out, signed by the student's academic adviser, and submitted to the department's student services manager by the end of the student's first quarter of study. Final revisions to the master's program proposal must be submitted no later than one academic quarter prior to the quarter of expected degree conferral. Stanford Materials Science undergraduates who are pursuing or who plan to pursue a Coterminal M.S. degree may have more flexibility in their programs and should consult with their academic advisers regarding appropriate core course and elective choices. The GRE (Graduate Record Examination) is required for admission to the M.S. program.

Degree requirements are as follows:

1. A minimum of 30 units of Materials Science and Engineering (MATSCI) course work, including core and lab courses specified below, all taken for a letter grade. Research units, one-unit seminars, MATSCI 299 Practical Training and courses in other departments (i.e., where students cannot enroll in a class with a MATSCI subject code) cannot be counted for this requirement.
2. Of these 30 units Materials Science requirements, students must include a or b.
    a. three classes from MATSCI 201-210 core courses and three MATSCI 171, 172, 173, 174, 175 laboratory courses. One laboratory requirement may be fulfilled by taking a lab course from another engineering department.

		Units
Select three of the following core courses:		
MATSCI 201	Applied Quantum Mechanics I	3
MATSCI 202	Materials Chemistry	3
MATSCI 203	Atomic Arrangements in Solids	3
MATSCI 204	Thermodynamics and Phase Equilibria	3
MATSCI 205	Waves and Diffraction in Solids	3
MATSCI 206	Defects in Crystalline Solids	3
MATSCI 207	Rate Processes in Materials	3
MATSCI 208	Mechanical Properties of Materials	3
MATSCI 209	Electronic and Optical Properties of Solids	3
MATSCI 210	Organic and Biological Materials	3
Total core course units		**9**
Select three of the following lab courses:		
MATSCI 170	Nanomaterials Laboratory	4
MATSCI 171	Energy Materials Laboratory	3
MATSCI 172	X-Ray Diffraction Laboratory	3
MATSCI 173	Mechanical Behavior Laboratory	3
MATSCI 174	Electronic and Photonic Materials and Devices Laboratory	3
MATSCI 175	Nanoscale Materials Physics Computation Laboratory	3
One laboratory requirment may be fulfilled by taking lab courses from another engineering dept.		
Total lab course units		**9**
TOTAL		**18**

    b. four classes from MATSCI 201-210 core courses and two MATSCI 171, 172, 173, 174, 175 laboratory courses. One laboratory requirement may be fulfilled by taking a lab course from another engineering department.

		Units
Select four of the following core courses:		
MATSCI 201	Applied Quantum Mechanics I	3
MATSCI 202	Materials Chemistry	3
MATSCI 203	Atomic Arrangements in Solids	3
MATSCI 204	Thermodynamics and Phase Equilibria	3
MATSCI 205	Waves and Diffraction in Solids	3
MATSCI 206	Defects in Crystalline Solids	3
MATSCI 207	Rate Processes in Materials	3
MATSCI 208	Mechanical Properties of Materials	3
MATSCI 209	Electronic and Optical Properties of Solids	3
MATSCI 210	Organic and Biological Materials	3
Total core course units		**12**
Select two of the following lab courses:		
MATSCI 171	Energy Materials Laboratory	3

MATSCI 172	X-Ray Diffraction Laboratory	3
MATSCI 173	Mechanical Behavior Laboratory	3
MATSCI 174	Electronic and Photonic Materials and Devices Laboratory	3
MATSCI 175	Nanoscale Materials Physics Computation Laboratory	3
One laboratory requirment may be fulfilled by taking lab courses from another engineering dept.		
Total lab course units		**6**
TOTAL		**18**

3. 15 units of approved course electives to result in a technically cohesive program. Of the 15 units of elective courses:
    a. 12 units must be taken for a letter grade (except for those submitting a M.S. thesis report).
    b. a maximum of three units may be seminars.
    c. if writing a master's thesis report, a minimum of 6 and a maximum of 15 units of MATSCI 200 Master's Research may be counted. Master's research units may be counted only if writing a M.S. thesis report. The final version of the thesis report must be signed off by two faculty and submitted to student services manager by last day of classes of the graduation quarter. See student services manager for details and approval.
    d. a maximum of three units may be undergraduate units, but not courses below the 100 level offering.
    e. a maximum of five units may be used for a foreign language course (not including any remedial English or courses in the student's native language if other than English). Students must plan to enroll in an upper level designation of a foreign language course offering.
    f. the combination of seminar, undergraduate, and language units may not exceed six units total.
    g. the combination of research, seminar, undergraduate, and language units may not exceed 15 units total.
    h. activity units may not be counted toward M.S. degree.
4. A minimum grade point average (GPA) of 2.75 for degree course work.

All proposed degree programs are subject to approval by student's academic adviser, and department's student services manager, who has responsibility for assuring that each proposal is a technically cohesive program. The M.S. degree is expected to be completed within two years during the University's candidacy period for completion of a master's degree.

Master's Thesis Report

Students wishing to take this option must consult with a MATSCI faculty member initially. Out of the 45 units M.S. degree requirements, 6-15 units may be taken in Materials Science Master's research by enrolling in MATSCI 200. Students using 15 units of research toward the degree must participate in a more complex and demanding research project than those using lesser units.

The M.S. thesis report must be approved and signed off by two faculty members. In general, one is student's research adviser, if adviser is a non MATSCI faculty member, a second MATSCI faculty is required to sign off on the thesis report. Consult with student services manager about faculty criteria, and requirements. Three copies of M.S. thesis report in final format should be submitted to two faculty advisers, and the department. The report is not an official University thesis but is intended to demonstrate to the department and faculty student's ability to conduct and report a directed research.

As a general guide line, a 6-9 units of master's research is a normal load for most students. The report should reflect the number of units taken. For instance, 3-4 laboratory reports are required for a 3-unit laboratory course. Accordingly, the level expected for 9 units of research would be at least equivalent to three such courses.

Students are advised to submit their thesis draft to faculty adviser readers by the end of fifth week of the quarter in which the units are to be assigned to allow time for faculty comments and revisions. A collated final version of the thesis report should be submitted to faculty and student services manager by last day of classes of student's graduation quarter. The appropriate grade for satisfactory progress in the research project prior to submission of the final report is 'N' (continuing); the 'S' (Satisfactory) final grade is given only when the report is fully approved and signed off by both faculty members.

In cases where students decide to pursue research after the initial program submission deadline, they should submit a revised M.S. Program Proposal at least two quarters before the degree is granted. The total combined units of Materials Science research units, seminars, language courses, and undergraduate courses cannot exceed 15. If a master's thesis report is not submitted, units in MATSCI 200 Master's Research cannot be applied to the department's requirement of 45 units for the conferral of the master's degree.

Honors Cooperative Program

Some of the department's graduate students participate in the Honors Cooperative Program (HCP), which makes it possible for academically qualified engineers and scientists in industry to be part-time graduate students in Materials Science while continuing professional employment. Prospective HCP students follow the same admissions process and must meet the same admissions requirements as full-time graduate students. For information regarding the Honors Cooperative Program, see Graduate Programs in the "School of Engineering (http://exploredegrees.stanford.edu/schoolofengineering/)" section of this bulletin.

Petition Process for Transfer from M.S. to Ph.D. Degree Program

Students admitted to graduate programs are admitted specifically into either the terminal M.S. or the Ph.D. program. A student admitted to the terminal M.S. program should not assume admission to the Ph.D. program. Admission to the Ph.D. program is required for a student to be eligible to work towards the Ph.D. degree.

A student in the terminal M.S. program may petition to be admitted to the Ph.D. program by filing an M.S. to Ph.D petition form. Petition must include a one-page statement of purpose explaining why the student wishes to transfer to the Ph.D. program, most recent unofficial transcript, and two letters of recommendation from members of the Stanford faculty, including one from the student's prospective research adviser and at least one from a Materials Science faculty member belonging to the Academic Council. The M.S. to Ph.D. petition to transfer should be submitted to the student services manager by June of the first year in the M.S. program. Students who wish to submit a petition to the Ph.D. degree, should plan to complete at least six of the MATSCI 200 series (including MATSCI 203 Atomic Arrangements in Solids, MATSCI 204 Thermodynamics and Phase Equilibria, MATSCI 207 Rate Processes in Materials) core courses during their first year of admission. A grade point average (GPA) of 3.5 or better in the core courses is requirement.

Transferring to the Ph.D. program is a competitive process and only highly qualified M.S. students may be admitted. Student's original application to the graduate program as well as the materials provided for the transfer petition are reviewed. Students must adhere to requirements for the terminal M.S. degree, and plan to confer the M.S. degree in the event that the Ph.D. petition to transfer is not approved.

Coterminal Master of Science Program in Materials Science and Engineering

Stanford undergraduates who wish to continue their studies for the Master of Science degree in Materials Science and Engineering through the Coterminal program may apply for admission after they have earned 120 units toward graduation (UTG) as shown on the undergraduate unofficial transcript. Applicants must submit their application no later than eight weeks before the start of the proposed admit quarter. The application must give evidence that student possesses a potential for strong academic performance at the graduate level. Scores from the Graduate Record Examination (GRE) General Test must be reported before action can be taken on an application.

Materials science is a highly integrated and interdisciplinary subject, therefore students of any engineering or science undergraduate major are encouraged to apply.

Information and other requirements pertaining to the Coterminal program in Materials Science and Engineering may be obtained from the department's student services manager.

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/cotermdegrees/)" section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate advisor be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Engineer in Materials Science Engineering

The University's basic requirements for the degree of Engineer are outlined in the "Graduate Degrees" section of this bulletin.

A student wishing to enter the Engineer program must have completed the requirements of the M.S. in Materials Science and Engineering, and must file a petition requesting admission to the program, stating the type of research to be done and the proposed supervising professor. Once approved, the Application for Candidacy must be submitted to the department's student services manager by the end of the second quarter in the Engineer program. Final changes in the Application for Candidacy form must be submitted no later than one academic quarter prior to degree conferral.

The 90-unit program must include 9 units of graduate courses in Materials Science with a MATSCI subject code (no research units, seminars, colloquia, and MATSCI 400 Participation in Materials Science Teaching, Participation in Teaching) beyond the requirements for the M.S. degree, and additional research or other units to meet the 90-unit University minimum requirement. A grade point average (GPA) of 3.0 must be maintained for all degree course work taken at Stanford.

The Engineer thesis must be approved and signed off by two Academic Council faculty members, one must be a MATSCI faculty member.

Doctor of Philosophy in Materials Science Engineering

The University's basic requirements for the Ph.D. degree are outlined in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/)" section of this bulletin. The GRE (Graduate Record Examination) is required for admission to the Ph.D. program.

The Ph.D. degree is awarded after the completion of a minimum of 135 units of graduate work as well as satisfactory completion of any additional University requirements. Degree requirements for the department are as follows:

		Units
Core Courses [1]		**30**
MATSCI 201	Applied Quantum Mechanics I	3
MATSCI 202	Materials Chemistry	3
MATSCI 203	Atomic Arrangements in Solids	3
MATSCI 204	Thermodynamics and Phase Equilibria	3
MATSCI 205	Waves and Diffraction in Solids	3
MATSCI 206	Defects in Crystalline Solids	3
MATSCI 207	Rate Processes in Materials	3
MATSCI 208	Mechanical Properties of Materials	3
MATSCI 209	Electronic and Optical Properties of Solids	3
MATSCI 210	Organic and Biological Materials	3
Five Elective Graduate Technical Courses [2]		**15**
Materials Science Colloquia [3]		**3**
MATSCI 230	Materials Science Colloquium (Autumn Quarter)	1
MATSCI 230	Materials Science Colloquium (Winter Quarter)	1
MATSCI 230	Materials Science Colloquium (Spring Quarter)	1
Research & Electives		**87**
75 Units of MATSCI 300: Ph.D. Research		75
12 Units of Electives [4]		12

[1] At least six of these courses must be taken during the first year (including MATSCI 203 Atomic Arrangements in Solids, MATSCI 204 Thermodynamics and Phase Equilibria, and MATSCI 207 Rate Processes in Materials) . All core courses must be completed for a letter grade, and taken during the first two years in the program.

[2] Elective technical courses must be in areas related directly to student's research interest in Materials Science and Engineering, and may not include MATSCI 230 Materials Science Colloquium, MATSCI 299 Practical Training, MATSCI 300 Ph.D. Research or MATSCI 400 Participation in Materials Science Teaching. All courses must be completed for a letter grade.

[3] Materials Science & Engineering Ph.D. students are required to take MATSCI 230 Materials Science Colloquium during each quarter of their first year. Attendance is required, roll is taken, and more than two absences results to an automatic "No Pass" grade.

[4] May include other engineering courses, or MATSCI 400 Participation in Materials Science Teaching or a maximum of 3 units MATSCI 299 Practical Training

- Students must consult with their academic adviser on Ph.D. course selection planning. For students with a non-MATSCI research adviser, the MATSCI academic/co-adviser must also approve the list of proposed courses. Any proposed deviations from the requirements can only be considered by petition.
- Ph.D. students are required to apply for and have conferred a MATSCI M.S. degree normally by the end of their third year of studies. A Graduate Program Authorization Petition (in Axess) and an M.S. Program Proposal (https://mse.stanford.edu/student-resources/forms/masters/) must be submitted after taking the Ph.D. qualifying examination.
- A departmental oral qualifying examination must be passed by the end of January of the second year. A grade point average (GPA) of 3.5 in core courses MATSCI 201-210 is required for admission to the Ph.D. qualifying examination. Students who have passed the Ph.D. qualifying examination are required to complete the Application for Candidacy to the Ph.D.degree by June of the second year after passing the qualifying examination. Final changes in the Application for Candidacy form must be submitted no later than one academic quarter prior to the Terminal Graduate Registration (TGR) Status.
- Maintain a cumulative GPA of 3.0 in all courses taken at Stanford.
- Students must present the results of their research dissertation at the University Ph.D. oral defense examination.
- Current students subject to either this set of requirements or a prior set must obtain the approval of their adviser before filing a revised program sheet, and should as far as possible adhere to the intent of the new requirements.
- Students may refer the list of "Advanced Specialty Courses and Cognate Courses" provided below as guidelines for their selection of technical elective units. As noted above, academic adviser approval is required.
- At least 90 units must be taken in residence at Stanford. Students entering with an M.S. degree in Materials Science from another university may request to transfer up to 45 units of equivalent work toward the total of 135 Ph.D. degree requirement units.
- Students may propose a petition for exemption from a required core course if they have taken a similar course in the past. To petition, a student must consult and obtain academic and/or research adviser approval, and consent of the instructor of the proposed core course. To assess a student's level of knowledge, the instructor may provide an oral or written examination on the subject matter. The student must pass the examination in order to be exempt from core course requirement. If the petition is approved, the student is required to complete the waived number of units by taking other relevant upper level MATSCI courses.

Advanced Specialty Courses

		Units
Biomaterials		
CHEMENG 310	Microhydrodynamics	3
CHEMENG 355	Advanced Biochemical Engineering	3
ME 381	Orthopaedic Bioengineering	3
ME 457	Fluid Flow in Microdevices	3
MATSCI 225	Biochips and Medical Imaging	3
MATSCI 380	Nano-Biotechnology	3
MATSCI 381	Biomaterials in Regenerative Medicine	3
Electronic Materials Processing		
EE 212	Integrated Circuit Fabrication Processes	3
EE 216	Principles and Models of Semiconductor Devices	3
EE 311	Advanced Integrated Circuits Technology	3
EE 316	Advanced VLSI Devices	3
EE 312	Integrated Circuit Fabrication Laboratory	3-4
MATSCI 312	New Methods in Thin Film Synthesis	3
Materials Characterization		
CHEMENG 345	Fundamentals and Applications of Spectroscopy	3
EE 329	The Electronic Structure of Surfaces and Interfaces	3
MATSCI 312	New Methods in Thin Film Synthesis	3
MATSCI 320	Nanocharacterization of Materials	3
MATSCI 321	Transmission Electron Microscopy	3
MATSCI 322	Transmission Electron Microscopy Laboratory	3
MATSCI 323	Thin Film and Interface Microanalysis	3
MATSCI 326	X-Ray Science and Techniques	3
Mechanical Behavior of Solids		
AA 252	Techniques of Failure Analysis	3
AA 256	Mechanics of Composites	3
MATSCI 251	Microstructure and Mechanical Properties	3-4
MATSCI 358	Fracture and Fatigue of Materials and Thin Film Structures	3
ME 335A	Finite Element Analysis	3
ME 335B	Finite Element Analysis	3
ME 335C	Finite Element Analysis	3
ME 340	Mechanics - Elasticity and Inelasticity	3
ME 345	Fatigue Design and Analysis	3
Physics of Solids and Computation		
APPPHYS 272	Solid State Physics	3
APPPHYS 273	Solid State Physics II	3
EE 222	Applied Quantum Mechanics I	3
EE 223	Applied Quantum Mechanics II	3
EE 327	Properties of Semiconductor Materials	3
EE 329	The Electronic Structure of Surfaces and Interfaces	3
MATSCI 331	Atom-based computational methods for materials	3
MATSCI 343	Organic Semiconductors for Electronics and Photonics	3
MATSCI 347	Magnetic materials in nanotechnology, sensing, and energy	3
Soft Materials		
CHEMENG 310	Microhydrodynamics	3
MATSCI 343	Organic Semiconductors for Electronics and Photonics	3
ME 455	Complex Fluids and Non-Newtonian Flows	3

Ph.D. Minor in Materials Science and Engineering

The University's basic requirements for the Ph.D. minor are outlined in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#doctoraltext)" section of this bulletin. A minor requires 20 units of graduate work of quality and depth at the 200-level or higher in the Materials Science and Engineering course offering. Courses must be taken for a letter grade. The proposed list of courses must be approved by department's advanced degree committee. Individual programs must be submitted to the student services manager at least one quarter prior to the quarter of the degree conferral. None of the units taken for the Ph.D. minor may overlap with any M.S. degree units.

COVID-19 Policies

On July 30, the Academic Senate adopted grading policies effective for all undergraduate and graduate programs, excepting the professional Graduate School of Business, School of Law, and the School of Medicine M.D. Program. For a complete list of those and other academic policies relating to the pandemic, see the "COVID-19 and Academic Continuity (http://exploredegrees.stanford.edu/covid-19-policy-changes/#tempdepttemplatetabtext)" section of this bulletin.

The Senate decided that all undergraduate and graduate courses offered for a letter grade must also offer students the option of taking the course for a “credit” or “no credit” grade and recommended that deans, departments, and programs consider adopting local policies to count courses taken for a “credit” or “satisfactory” grade toward the fulfillment of degree-program requirements and/or alter program requirements as appropriate.

Undergraduate Degree Requirements

Grading

The Department of Materials Science and Engineering counts all courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of undergraduate degree requirements that otherwise require a letter grade.

Undergraduates who are unable to enroll in certain courses, such as laboratory courses, WIM courses, or other specific major requirements, should contact the MatSci Student Services Office to facilitate an alternative course plan. In some cases, students may be able to substitute a major requirement with an alternative course in the department. Program deviations will be handled on a case by case basis. Any requests must be initiated by the student by emailing msestudentservices@stanford.edu.

Other Undergraduate Policies

Students are strongly encouraged to request a CR/NC grading option well in advance of the change of grading basis deadline (Friday of Week 8 of each quarter) and must notify their instructor of any grading basis changes as soon as they occur. Additionally, students should carefully consider their options before taking a large number of major courses with a CR/NC grading option as this may impact employment opportunities, fellowship applications, or graduate school admissions. Students are encouraged to reach out to the Director of Undergraduate Studies, Dr. Rajan Kumar, for additional assistance regarding grading options for the 2020-21 academic year.

Graduate Degree Requirements

Grading

The Department of Materials Science and Engineering counts all non-core courses taken in academic year 2020-21 with a grade of 'CR' (credit) or 'S' (satisfactory) towards satisfaction of graduate degree requirements that otherwise require a letter grade provided that the instructor affirms that the work was done at a 'C-' or better level.

All Materials Science and Engineering graduate-level core courses must be taken for letter-grade. These courses are MATSCI 201-214. All other courses at the graduate level may be taken for letter grade or CR/NC.

Other Graduate Policies

Graduate students should carefully consider their options before taking a large number of major courses with a CR/NC grading option, as this may impact employment opportunities, fellowship applications, or further graduate school admissions. Students are encouraged to reach out to the MatSci Ph.D. Advising Team or the MatSci Student Services Office for additional assistance regarding grading options for the 2020-21 academic year.

Graduate Advising Expectations

The Department of Materials Science and Engineering is committed to providing academic advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the adviser and the advisee. As a best practice, advising expectations should be periodically discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

Faculty advisers guide students in key areas such as selecting courses, designing and conducting research, developing of teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways.

Graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program.

For a statement of University policy on graduate advising, see the "Graduate Advising (http://exploredegrees.stanford.edu/graduatedegrees/#advisingandcredentialstext)" section of this bulletin.

M.S. Advising

The Department of Materials Science and Engineering (MSE) is committed to providing academic advising in support of its M.S. students’ education and professional development. When most effective, this advising relationship entails collaborative engagement by both the adviser and the advisee. As a best practice, advising expectations should be discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

At the start of graduate study, each student is assigned a master’s program adviser, a member of department faculty who provides guidance in course selection and in exploring academic opportunities and professional pathways. Usually, the same faculty member serves as program adviser for the duration of master’s study, but the handbook does describe a process for formal adviser changes.

The MSE Graduate Handbook (https://mse.stanford.edu/student-resources/) provides information and suggested timelines for advising meetings; however, ideally, the program adviser and student meet at least three times during the student’s two-year degree. The first meeting between program adviser and student should occur once in Autumn Quarter of the first year to discuss the student’s goals and objectives. Student and program adviser meet again in Spring Quarter to discuss the student’s course plans and goals for the next academic year. The last meeting should be at the start of the quarter before the student’s final quarter of study, and the program adviser and student review the student’s coursework taken and the final quarter of study courses the student intends to take. It is expected that the student initiates these meetings.

In addition, the faculty Director of Graduate Studies (DGS) meets all the master’s students during the MSE Orientation at the start of the first year and is available during the academic year by email and during office hours.The DGS or program adviser may initiate a meeting with any student they feel could be in academic distress.

The MSE student services team is also an important part of the master’s advising team. They inform students and advisers about University and department requirements, procedures, and opportunities, and maintain the official records of advising assignments and approvals.

Finally, the department believes that graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program. As such, it expects students to read the monthly MSE Updates newsletter, which provides deadlines, web links, and other valuable information on graduate degree progress.

Ph.D. Advising

The Department of Materials Science and Engineering (MSE) is committed to providing academic advising in support of its Ph.D. students' education and professional development. When most effective, this advising relationship entails collaborative engagement by both the adviser and the advisee. As a best practice, advising expectations should be discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

Faculty advisers guide students in key areas such as selecting courses, designing and conducting research, developing teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways. The MSE Graduate Handbook (https://mse.stanford.edu/student-resources/) provides information and suggested timelines for advising meetings in the different stages of the doctoral program, and this timeline is reviewed in the MSE Orientation held at the start of a student's doctoral program and at the annual MSE Graduate Updates meeting.

Ph.D. students are initially assigned a doctoral program adviser based on the interests expressed in their application. This faculty member provides initial guidance in course selection, assists students in exploring academic opportunities and professional pathways, and aids in identifying doctoral research opportunities. MSE does not require formal lab rotations, but students are strongly encouraged to explore research activities in two or three labs during their first academic year.

Students identify their doctoral research adviser prior to the end of February of their first year of study. The research supervisor assumes primary responsibility for the future direction of the student, taking on the roles previously filled by the program adviser, and ultimately directs the student's dissertation. Most students find an adviser from among the primary faculty members of the department. However, the research adviser may be a faculty member from another Stanford department who is familiar with supervising doctoral students and able to provide both research advising and funding for the duration of the doctoral program. When the research adviser is from outside the department, the student must also identify a department co-adviser from the department's primary faculty to provide guidance on departmental requirements, core coursework, and opportunities.

The faculty Director of Graduate Studies (DGS) meets with all the doctoral students during the MSE Orientation at the start of the first year and is available during the academic year by email and during office hours. The DGS or research adviser/co-adviser may initiate a meeting with any student they feel could be in academic or research distress.

The MSE student services team is also an important part of the doctoral advising team: they inform students and advisers about University and department requirements, procedures, and opportunities, and they maintain the official records of advising assignments and approvals. Students are encouraged to talk with the DGS and the student services office as they consider adviser selection, or for guidance in working with their adviser(s). Student services can discuss how a student can change program/research adviser(s), declare their Dissertation Reading Committee/Oral Exam Committee, and process for filing important paperwork.

The department's doctoral students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program. As such the department expects students to read the monthly MSE Updates newsletter which provides deadlines, web links, and other valuable information on graduate degree progress.

Chair: Alberto Salleo

Director of Graduate Studies: Eric Appel

Director of Undergraduate Studies: Rajan Kumar

Associate Chair: Sarah C. Heilshorn

Professors: Mark L. Brongersma, Bruce M. Clemens, Yi Cui, Reinhold H. Dauskardt, Thomas Devereaux, Persis S. Drell, Paul C. McIntyre, Nicholas A. Melosh, Friedrich B. Prinz, Alberto Salleo, Robert Sinclair, Shan X. Wang

Associate Professors: William Chueh, Jennifer A. Dionne, Sarah C. Heilshorn, Aaron M. Lindenberg, Evan J. Reed, Andrew Spakowitz

Assistant Professors: Eric Appel, Felipe da Jornada, Guosong Hong, Andrew Mannix, Kunal Mukherjee

Courtesy Professors: Raag Airan, Zhenan Bao, Stacey F. Bent, Wei Cai, Matteo Cargnello, Christopher Chidsey, Ian R. Fisher, Curtis W. Frank, David Goldhaber-Gordon, Kenneth Goodson, Sanjiv Sam Gambhir, Wendy Gu, Geoffrey C. Gurtner, Michael T. Longaker, Arunava Majumdar, James D. Plummer, Eric Pop, Krishna Saraswat, Jonathan Stebbins, Yuri Suzuki, Peter Yang, Xiaolin Zheng

Lecturers: Rajan Kumar, Ann Marshall, Arturas Vailionis

Adjunct Professors: Khalil Amine, Geraud Dubois, Annika Enejder, Turgut Gur, Bryce Meredig, Hendrik Ohldag

Emeriti: (Professors) David M. Barnett, Clayton W. Bates Jr., Arthur Bienenstock, John C. Bravman, Richard H. Bube, Theodore H. Geballe, Robert A. Huggins, William D. Nix, John C. Shyne, William A. Tiller, Robert L. White, Robert S. Feigelson *(Professor, Research)*

Cognate Courses

		Units
AA 252	Techniques of Failure Analysis	3
AA 256	Mechanics of Composites	3
APPPHYS 270	Magnetism and Long Range Order in Solids	3
APPPHYS 272	Solid State Physics	3
APPPHYS 273	Solid State Physics II	3
CHEMENG 310	Microhydrodynamics	3
CHEMENG 345	Fundamentals and Applications of Spectroscopy	3
CHEMENG 355	Advanced Biochemical Engineering	3
EE 212	Integrated Circuit Fabrication Processes	3
EE 216	Principles and Models of Semiconductor Devices	3
EE 222	Applied Quantum Mechanics I	3
EE 223	Applied Quantum Mechanics II	3
EE 311	Advanced Integrated Circuits Technology	3
EE 312	Integrated Circuit Fabrication Laboratory	3-4
EE 316	Advanced VLSI Devices	3
EE 327	Properties of Semiconductor Materials	3

EE 329	The Electronic Structure of Surfaces and Interfaces	3
ENGR 50	Introduction to Materials Science, Nanotechnology Emphasis	4
ENGR 50E	Introduction to Materials Science, Energy Emphasis	4
ENGR 50M	Introduction to Materials Science, Biomaterials Emphasis	4
ME 329	Mechanical Analysis in Design	3
ME 335A	Finite Element Analysis	3
ME 335B	Finite Element Analysis	3
ME 335C	Finite Element Analysis	3
ME 345	Fatigue Design and Analysis	3
ME 381	Orthopaedic Bioengineering	3
ME 455	Complex Fluids and Non-Newtonian Flows	3
ME 457	Fluid Flow in Microdevices	3
PHYSICS 230	Graduate Quantum Mechanics I	3
PHYSICS 231	Graduate Quantum Mechanics II	3

Courses

MATSCI 10. Materials Matter. 1 Unit.
All facets of engineering rely on materials to develop modern devices and solve the greatest technological challenges in society today. In this introductory 1-unit course, students will learn about the field of Materials Science and Engineering and its broad applications in research and industry. Students who are interested in careers in energy and sustainability, biomaterials and regenerative medicine, or engineering matter at the atomic scale for electronics and nanotechnology will be able to have an early window into the work done in these areas through this course. Each week, students will listen to talks from invited guest speakers and discover the wide variety of career opportunities and areas of focus offered through Materials Science and Engineering. Additionally, students will have the opportunity to develop networks with Stanford alumni and current students in our department. This course is open to all undergraduates and does not have any pre-requisites.

MATSCI 31. Chemical Principles: From Molecules to Solids. 5 Units.
A one-quarter course for students who have taken chemistry previously. This course will introduce the basic chemical principles that dictate how and why reactions occur and the structure and properties of important molecules and extended solids that make up our world. As the Central Science, a knowledge of chemistry provides a deep understanding of concepts in fields ranging from materials, environmental science, and engineering to pharmacology and metabolism. Discussions of molecular structure will describe bonding models including Lewis structures, resonance, crystal-field theory, and molecular-orbital theory. We will reveal the chemistry of materials of different dimensionality, with emphasis on symmetry, bonding, and electronic structure of molecules and solids. We will also discuss the kinetics and thermodynamics that govern reactivity and dictate solubility and acid-base equilibria. A two-hour weekly laboratory section accompanies the course to introduce laboratory techniques and reiterate lecture concepts through hands-on activities. Specific discussions will include the structure, properties, and applications of molecules used in medicine, perovskites used in solar cells, and the dramatically different properties of materials with the same composition (for example: diamond, graphite, graphene). There will be three lectures, one two-hour laboratory session, and an optional 80-minute problem solving session each week. The course will assume familiarity with stoichiometry, unit conversions, and gas laws. All students who are interested in taking general chemistry at Stanford must take the Autumn 2020 General Chemistry Placement Test before Autumn quarter begins, regardless of chemistry background. Generally students earning an AP chemistry score of 4 or higher place into 31M. Students earning an AP score of 5 are also welcome to take the Autumn 2020 Chemistry 33 Placement Test to see if Chem33 is a more appropriate placement. Same as: MATSCI 31.
Same as: CHEM 31M

MATSCI 81N. Bioengineering Materials to Heal the Body. 3 Units.
Preference to freshmen. Real-world examples of materials developed for tissue engineering and regenerative medicine therapies. How scientists and engineers design new materials for surgeons to use in replacing body parts such as damaged heart or spinal cord tissue. How cells interact with implanted materials. Students identify a clinically important disease or injury that requires a better material, proposed research approaches to the problem, and debate possible engineering solutions.

MATSCI 82N. Science of the Impossible. 3 Units.
Imagine a world where cancer is cured with light, objects can be made invisible, and teleportation is allowed through space and time. The future once envisioned by science fiction writers is now becoming a reality, thanks to advances in materials science and engineering. This seminar will explore 'impossible' technologies - those that have shaped our past and those that promise to revolutionize the future. Attention will be given to both the science and the societal impact of these technologies. We will begin by investigating breakthroughs from the 20th century that seemed impossible in the early 1900s, such as the invention of integrated circuits and the discovery of chemotherapy. We will then discuss the scientific breakthroughs that enabled modern 'impossible' science, such as photodynamic cancer therapeutics, invisibility, and psychokinesis through advanced mind-machine interfaces. Lastly, we will explore technologies currently perceived as completely impossible and brainstorm the breakthroughs needed to make such science fiction a reality. The course will include introductory lectures and in-depth conversations based on readings. Students will also be given the opportunity to lead class discussions on a relevant 'impossible science' topic of their choosing.

MATSCI 83N. Great Inventions That Matter. 3 Units.
This introductory seminar starts by illuminating on the general aspects of creativity, invention, and patenting in engineering and medicine, and how Stanford University is one of the world's foremost engines of innovation. We then take a deep dive into some great technological inventions which are still playing an essential role in our everyday lives, such as fiber amplifier, digital compass, computer memory, HIV detector, personal genome machine, cancer cell sorting, brain imaging, and mind reading. The stories and underlying materials and technologies behind each invention, including a few examples by Stanford faculty and student inventors, are highlighted and discussed. A special lecture focuses on the public policy on intellectual properties (IP) and the resources at Stanford Office of Technology Licensing (OTL). Each student will have an opportunity to present on a great invention from Stanford (or elsewhere), or to write a (mock) patent disclosure of his/her own ideas.

MATSCI 85N. Health Fab: Making Stuff for Life. 3 Units.
Semiconductor-based chip technology is all around us; in our phones, computers, and cars. However, not all capabilities developed for silicon processing are directed towards computers and mobile devices. A new field has emerged using these fabrication and patterning techniques for medical devices, health monitoring, and human-machine interfaces. We can now create chips that flow not electrons, but liquids, taking samples and performing analyses. These liquid based functions can be integrated together with silicon electronic devices for sensing, control, or manipulation. FitBits and Apple Watches are examples of the first generation of 'wearable' electronics, while more advanced devices that incorporate both liquid based sensors and electronics are on their way.nnIn this class, we will learn some fundamentals of device fabrication for biomedical purposes, take you inside the Stanford NanoFabrication Facility (SNF), and create microfluidic devices. We will cover what is possible with current microfabrication techniques, including direct-write lithography, laser cutting, three-dimensional two photon patterning, polymer deposition and metal patterning. Students will learn how to design, fabricate, and test microfluidic and biomedically related devices. In addition to teaching and hands-on training in microfluidic fabrication, the class will include four team-based projects, each with a different device goal. These projects requirements will be submitted by leading research groups at Stanford, providing up-to-date and real world challenges. Each team will work together to identify specific device needs, invent solutions, and built prototype devices. At the end of the course each team will present its designs to the sponsoring research program and describe how they met the required objectives. No prior experience with device fabrication is needed.

MATSCI 90Q. Resilience, Transformation, and Equilibrium: the Science of Materials. 3-4 Units.
In this course, we will explore the fundamentals of the kinetics of materials while relating them to different phenomena that we observe in our everyday lives. We will study the mechanisms and processes by which materials obtain the mechanical, electronic, and other properties that make them so useful to us. How can we cool water below freezing and keep it from turning into ice? Why is it that ice cream that has been in the freezer for too long does not taste as good? What are crystal defects and why do they help create some of the most useful (semiconductors) and beautiful (gemstones) things we have? This introductory seminar is open to all students, and prior exposure to chemistry, physics, or calculus is NOT required.

MATSCI 100. Undergraduate Independent Study. 1-3 Unit.
Independent study in materials science under supervision of a faculty member.

MATSCI 142. Quantum Mechanics of Nanoscale Materials. 4 Units.
Introduction to quantum mechanics and its application to the properties of materials. No prior background beyond a working knowledge of calculus and high school physics is presumed. Topics include: The Schrodinger equation and applications to understanding of the properties of quantum dots, semiconductor heterostructures, nanowires, and bulk solids. Tunneling processes and applications to nanoscale devices; the scanning tunneling microscope, and quantum cascade lasers. Simple models for the electronic properties and band structure of materials including semiconductors, insulators and metals and applications to semiconductor devices. Time-dependent perturbation theory and interaction of light with materials with applications to laser technology. Recommended: ENGR 50 or equivalent introductory materials science course. (Formerly 157).

MATSCI 143. Materials Structure and Characterization. 4 Units.
Students will study the theory and application of characterization techniques used to examine the structure of materials at the nanoscale. Students will learn to classify the structure of materials such as semiconductors, ceramics, metals, and nanotubes according to the principles of crystallography. Methods used widely in academic and industrial research, including X-ray diffraction and electron microscopy, will be demonstrated along with their application to the analysis of nanostructures. Prerequisites: E-50 or equivalent introductory materials science course. (Formerly 153).

MATSCI 144. Thermodynamic Evaluation of Green Energy Technologies. 4 Units.
Understand the thermodynamics and efficiency limits of modern green technologies such as carbon dioxide capture from air, fuel cells, batteries, and solar-thermal power. Recommended: ENGR 50 or equivalent introductory materials science course. (Formerly 154).

MATSCI 145. Kinetics of Materials Synthesis. 4 Units.
The science of synthesis of nanometer scale materials. Examples including solution phase synthesis of nanoparticles, the vapor-liquid-solid approach to growing nanowires, formation of mesoporous materials from block-copolymer solutions, and formation of photonic crystals. Relationship of the synthesis phenomena to the materials science driving forces and kinetic mechanisms. Materials science concepts including capillarity, Gibbs free energy, phase diagrams, and driving forces. Prerequisites: MatSci 144. (Formerly 155).

MATSCI 150. Undergraduate Research. 1-6 Unit.
Participation in a research project.

MATSCI 151. Microstructure and Mechanical Properties. 3-4 Units.
Primarily for students without a materials background. Mechanical properties and their dependence on microstructure in a range of engineering materials. Elementary deformation and fracture concepts, strengthening and toughening strategies in metals and ceramics. Topics: dislocation theory, mechanisms of hardening and toughening, fracture, fatigue, and high-temperature creep. Undergraduates register in 151 for 4 units; graduates register for 251 in 3 units.
Same as: MATSCI 251

MATSCI 152. Electronic Materials Engineering. 4 Units.
Materials science and engineering for electronic device applications. Kinetic molecular theory and thermally activated processes; band structure; electrical conductivity of metals and semiconductors; intrinsic and extrinsic semiconductors; elementary p-n junction theory; operating principles of light emitting diodes, solar cells, thermoelectric coolers, and transistors. Semiconductor processing including crystal growth, ion implantation, thin film deposition, etching, lithography, and nanomaterials synthesis.

MATSCI 156. Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution. 3-4 Units.
Operating principles and applications of emerging technological solutions to the energy demands of the world. The scale of global energy usage and requirements for possible solutions. Basic physics and chemistry of solar cells, fuel cells, and batteries. Performance issues, including economics, from the ideal device to the installed system. The promise of materials research for providing next generation solutions. Undergraduates register in 156 for 4 units; graduates register in 256 for 3 units. Prerequisites: MATSCI 145 and 152 or equivalent coursework in thermodynamics and electronic properties.

MATSCI 158. Soft Matter in Biomedical Devices, Microelectronics, and Everyday Life. 4 Units.
The relationships between molecular structure, morphology, and the unique physical, chemical, and mechanical behavior of polymers and other types of soft matter are discussed. Topics include methods for preparing synthetic polymers and examination of how enthalpy and entropy determine conformation, solubility, mechanical behavior, microphase separation, crystallinity, glass transitions, elasticity, and linear viscoelasticity. Case studies covering polymers in biomedical devices and microelectronics will be covered. Recommended: ENGR 50 and Chem 31A or equivalent.
Same as: BIOE 158

MATSCI 159Q. Japanese Companies and Japanese Society. 3 Units.
Preference to sophomores. The structure of a Japanese company from the point of view of Japanese society. Visiting researchers from Japanese companies give presentations on their research enterprise. The Japanese research ethic. The home campus equivalent of a Kyoto SCTI course.
Same as: ENGR 159Q

MATSCI 160. Nanomaterials Laboratory. 3-4 Units.
This course is designed for students interested in exploring the cutting edge of nanoscience and nanotechnology. Students will learn several fundamental concepts related to nanomaterials synthesis and characterization that are commonly used in research and industrial settings. Students will also investigate several applications of nanomaterials through a series of assessments, including self-assembled monolayers, nanowire photovoltaics, and nanoparticles for drug delivery and biomarker screening. In lieu of traditional labs, students will attend weekly discussion sections aimed at priming students to think like a materials engineer. Through these discussions, students will explore how to design an effective experiment, how to identify research gaps, and how to write an effective grant proposal. Enrollment limited to 24. Prerequisites: ENGR 50. Contact instructor for more details. Undergraduates register for 160 for 4 units, Graduates register for 170 for 3 units.
Same as: MATSCI 170

MATSCI 161. Energy Materials Laboratory. 3-4 Units.
From early church architecture through modern housing, windows are passages of energy and matter in the forms of light, sound and air. By letting in heat during the summer and releasing it in winter, windows can place huge demands on air conditioning and heating systems, thereby increasing energy consumption and raising greenhouse gas levels in the atmosphere. Latest advances in materials science have enabled precise and on-demand control of electromagnetic radiation through `smart¿ dynamic windows with photochromic and electrochromic materials that change color and optical density in response to light radiance and electrical potential. In this course, we will spend the whole quarter on a project to make and characterize dynamic windows based on one of the electrochromic material systems, the reversible electroplating of metal alloys. There will be an emphasis in this course on characterization methods such as scanning electron microscopy, x-ray photoelectron spectroscopy, optical spectroscopy, four-point probe measurements of conductivity and electrochemical measurements (cyclic voltammetry). The course will finish with students giving presentations on the prospects of using dynamic windows and generic radiation control in cars, homes, commercial buildings or airplanes. Undergraduates register for 161 for 4 units; graduates register for 171 for 3 units.
Same as: MATSCI 171

MATSCI 162. X-Ray Diffraction Laboratory. 3-4 Units.
Experimental x-ray diffraction techniques for microstructural analysis of materials, emphasizing powder and single-crystal techniques. Diffraction from epitaxial and polycrystalline thin films, multilayers, and amorphorous materials using medium and high resolution configurations. Determination of phase purity, crystallinity, relaxation, stress, and texture in the materials. Advanced experimental x-ray diffraction techniques: reciprocal lattice mapping, reflectivity, and grazing incidence diffraction. Enrollment limited to 20. Undergraduates register for 162 for 4 units; graduates register for 172 for 3 units. Prerequisites: MATSCI 143 or equivalent course in materials characterization.
Same as: MATSCI 172, PHOTON 172

MATSCI 163. Mechanical Behavior Laboratory. 3-4 Units.
Technologically relevant experimental techniques for the study of the mechanical behavior of engineering materials in bulk and thin film form, including tension testing, nanoindentation, and wafer curvature stress analysis. Metallic and polymeric systems. Register for lecture section in addition to one lab section. Undergraduates register for 163 in 4 units; graduates register in 173 for 3 units.
Same as: MATSCI 173

MATSCI 164. Electronic and Photonic Materials and Devices Laboratory. 3-4 Units.
Lab course. Current electronic and photonic materials and devices. Device physics and micro-fabrication techniques. Students design, fabricate, and perform physical characterization on the devices they have fabricated. Established techniques and materials such as photolithography, metal evaporation, and Si technology; and novel ones such as soft lithography and organic semiconductors. Prerequisite: MATSCI 152 or 199 or consent of instructor. Undergraduates register in 164 for 4 units; graduates register in 174 for 3 units. Students are required to sign up for lecture and one lab section.
Same as: MATSCI 174

MATSCI 165. Nanoscale Materials Physics Computation Laboratory. 3-4 Units.
Computational exploration of fundamental topics in materials science using Java-based computation and visualization tools. Emphasis is on the atomic-scale origins of macroscopic materials phenomena. Simulation methods include molecular dynamics and Monte Carlo with applications in thermodynamics, kinetics, and topics in statistical mechanics. Undergraduates register for 165 for 4 units; graduates register for 175 for 3 units. Prerequisites: Undergraduate physics and MATSCI 144 or equivalent coursework in thermodynamics. MATSCI 145 recommended.
Same as: MATSCI 175

MATSCI 166. Data Science and Machine Learning Approaches in Chemical and Materials Engineering. 3 Units.
Application of Data Science, Statistical Learning, and Machine Learning approaches to modern problems in Chemical and Materials Engineering. This course develops data science approaches, including their foundational mathematical and statistical basis, and applies these methods to data sets of limited size and precision. Methods for regression and clustering will be developed and applied, with an emphasis on validation and error quantification. Techniques that will be developed include linear and nonlinear regression, clustering and logistic regression, dimensionality reduction, unsupervised learning, neural networks, and hidden Markov models. These methods will be applied to a range of engineering problems, including conducting polymers, water purification membranes, battery materials, disease outcome prediction, genomic analysis, organic synthesis, and quality control in manufacturing. Prerequisites: CS 106A or permission from instructor.
Same as: CHEMENG 177, CHEMENG 277, MATSCI 176

MATSCI 170. Nanomaterials Laboratory. 3-4 Units.
This course is designed for students interested in exploring the cutting edge of nanoscience and nanotechnology. Students will learn several fundamental concepts related to nanomaterials synthesis and characterization that are commonly used in research and industrial settings. Students will also investigate several applications of nanomaterials through a series of assessments, including self-assembled monolayers, nanowire photovoltaics, and nanoparticles for drug delivery and biomarker screening. In lieu of traditional labs, students will attend weekly discussion sections aimed at priming students to think like a materials engineer. Through these discussions, students will explore how to design an effective experiment, how to identify research gaps, and how to write an effective grant proposal. Enrollment limited to 24. Prerequisites: ENGR 50. Contact instructor for more details. Undergraduates register for 160 for 4 units, Graduates register for 170 for 3 units.
Same as: MATSCI 160

MATSCI 171. Energy Materials Laboratory. 3-4 Units.
From early church architecture through modern housing, windows are passages of energy and matter in the forms of light, sound and air. By letting in heat during the summer and releasing it in winter, windows can place huge demands on air conditioning and heating systems, thereby increasing energy consumption and raising greenhouse gas levels in the atmosphere. Latest advances in materials science have enabled precise and on-demand control of electromagnetic radiation through `smart¿ dynamic windows with photochromic and electrochromic materials that change color and optical density in response to light radiance and electrical potential. In this course, we will spend the whole quarter on a project to make and characterize dynamic windows based on one of the electrochromic material systems, the reversible electroplating of metal alloys. There will be an emphasis in this course on characterization methods such as scanning electron microscopy, x-ray photoelectron spectroscopy, optical spectroscopy, four-point probe measurements of conductivity and electrochemical measurements (cyclic voltammetry). The course will finish with students giving presentations on the prospects of using dynamic windows and generic radiation control in cars, homes, commercial buildings or airplanes. Undergraduates register for 161 for 4 units; graduates register for 171 for 3 units.
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MATSCI 172. X-Ray Diffraction Laboratory. 3-4 Units.
Experimental x-ray diffraction techniques for microstructural analysis of materials, emphasizing powder and single-crystal techniques. Diffraction from epitaxial and polycrystalline thin films, multilayers, and amorphorous materials using medium and high resolution configurations. Determination of phase purity, crystallinity, relaxation, stress, and texture in the materials. Advanced experimental x-ray diffraction techniques: reciprocal lattice mapping, reflectivity, and grazing incidence diffraction. Enrollment limited to 20. Undergraduates register for 162 for 4 units; graduates register for 172 for 3 units. Prerequisites: MATSCI 143 or equivalent course in materials characterization.
Same as: MATSCI 162, PHOTON 172

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Same as: MATSCI 163

MATSCI 174. Electronic and Photonic Materials and Devices Laboratory. 3-4 Units.
Lab course. Current electronic and photonic materials and devices. Device physics and micro-fabrication techniques. Students design, fabricate, and perform physical characterization on the devices they have fabricated. Established techniques and materials such as photolithography, metal evaporation, and Si technology; and novel ones such as soft lithography and organic semiconductors. Prerequisite: MATSCI 152 or 199 or consent of instructor. Undergraduates register in 164 for 4 units; graduates register in 174 for 3 units. Students are required to sign up for lecture and one lab section.
Same as: MATSCI 164

MATSCI 175. Nanoscale Materials Physics Computation Laboratory. 3-4 Units.
Computational exploration of fundamental topics in materials science using Java-based computation and visualization tools. Emphasis is on the atomic-scale origins of macroscopic materials phenomena. Simulation methods include molecular dynamics and Monte Carlo with applications in thermodynamics, kinetics, and topics in statistical mechanics. Undergraduates register for 165 for 4 units; graduates register for 175 for 3 units. Prerequisites: Undergraduate physics and MATSCI 144 or equivalent coursework in thermodynamics. MATSCI 145 recommended.
Same as: MATSCI 165

MATSCI 176. Data Science and Machine Learning Approaches in Chemical and Materials Engineering. 3 Units.
Application of Data Science, Statistical Learning, and Machine Learning approaches to modern problems in Chemical and Materials Engineering. This course develops data science approaches, including their foundational mathematical and statistical basis, and applies these methods to data sets of limited size and precision. Methods for regression and clustering will be developed and applied, with an emphasis on validation and error quantification. Techniques that will be developed include linear and nonlinear regression, clustering and logistic regression, dimensionality reduction, unsupervised learning, neural networks, and hidden Markov models. These methods will be applied to a range of engineering problems, including conducting polymers, water purification membranes, battery materials, disease outcome prediction, genomic analysis, organic synthesis, and quality control in manufacturing. Prerequisites: CS 106A or permission from instructor.
Same as: CHEMENG 177, CHEMENG 277, MATSCI 166

MATSCI 190. Organic and Biological Materials. 3-4 Units.
Unique physical and chemical properties of organic materials and their uses. The relationship between structure and physical properties, and techniques to determine chemical structure and molecular ordering. Examples include liquid crystals, dendrimers, carbon nanotubes, hydrogels, and biopolymers such as lipids, protein, and DNA. Prerequisite: Thermodynamics and ENGR 50 or equivalent. Undergraduates register for 190 for 4 units; graduates register for 210 for 3 units.
Same as: MATSCI 210

MATSCI 192. Materials Chemistry. 3-4 Units.
An introduction to the fundamental physical chemical principles underlying materials properties. Beginning from basic quantum chemistry, students will learn how the electronic configuration of molecules and solids impacts their structure, stability/reactivity, and spectra. Topics for the course include molecular symmetry, molecular orbital theory, solid-state chemistry, coordination compounds, and nanomaterials chemistry. Using both classroom lectures and journal discussions, students will gain an understanding of and be well-positioned to contribute to the frontiers of materials chemistry, ranging from solar-fuel generation to next-generation cancer treatments. Undergraduates register in 192 for 4 units; graduates register in 202 for 3 units.
Same as: MATSCI 202

MATSCI 193. Atomic Arrangements in Solids. 3-4 Units.
Atomic arrangements in perfect and imperfect solids, especially important metals, ceramics, and semiconductors. Elements of formal crystallography, including development of point groups and space groups. Undergraduates register in 193 for 4 units; graduates register in 203 for 3 units.
Same as: MATSCI 203

MATSCI 194. Thermodynamics and Phase Equilibria. 3-4 Units.
The principles of heterogeneous equilibria and their application to phase diagrams. Thermodynamics of solutions; chemical reactions; non-stoichiometry in compounds; first order phase transitions and metastability; thermodynamics of surfaces, elastic solids, dielectrics, and magnetic solids. Undergraduates register for 194 for 4 units; graduates register for 204 for 3 units.

MATSCI 195. Waves and Diffraction in Solids. 3-4 Units.
The elementary principals of x-ray, vibrational, and electron waves in solids. Basic wave behavior including Fourier analysis, interference, diffraction, and polarization. Examples of wave systems, including electromagnetic waves from Maxwell's equations. Diffracted intensity in reciprocal space and experimental techniques such as electron and x-ray diffraction. Lattice vibrations in solids, including vibrational modes, dispersion relationship, density of states, and thermal properties. Free electron model. Basic quantum mechanics and statistical mechanics including Fermi-Dirac and Bose-Einstein statistics. Prerequisite: MATSCI 193/203 or consent of instructor. Undergraduates register for 195 for 4 units; graduates register for 205 for 3 units.
Same as: MATSCI 205, PHOTON 205

MATSCI 196. Defects in Crystalline Solids. 3-4 Units.
Thermodynamic and kinetic behaviors of 0-D (point), 1-D (line), and 2-D (interface and surface) defects in crystalline solids. Influences of these defects on the macroscopic ionic, electronic, and catalytic properties of materials, such as batteries, fuel cells, catalysts, and memory-storage devices. Undergraduates register for 196 for 4 units; graduates register for 206 for 3 units.
Same as: MATSCI 206

MATSCI 197. Rate Processes in Materials. 3-4 Units.
Diffusion and phase transformations in solids. Diffusion topics: Fick's laws, atomic theory of diffusion, and diffusion in alloys. Phase transformation topics: nucleation, growth, diffusional transformations, spinodal decomposition, and interface phenomena. Material builds on the mathematical, thermodynamic, and statistical mechanical foundations in the prerequisites. Prerequisites: MATSCI 194/204. Undergraduates register for 197 for 4 units; graduates register for 207 for 3 units.
Same as: MATSCI 207

MATSCI 198. Mechanical Properties of Materials. 3-4 Units.
Introduction to the mechanical behavior of solids, emphasizing the relationships between microstructure and mechanical properties. Elastic, anelastic, and plastic properties of materials. The relations between stress, strain, strain rate, and temperature for plastically deformable solids. Application of dislocation theory to strengthening mechanisms in crystalline solids. The phenomena of creep, fracture, and fatigue and their controlling mechanisms. Prerequisites: MATSCI 193/203. Undergraduates register for 198 for 4 units; graduates register for 208 for 3 units.
Same as: MATSCI 208

MATSCI 199. Electronic and Optical Properties of Solids. 3-4 Units.
The concepts of electronic energy bands and transports applied to metals, semiconductors, and insulators. The behavior of electronic and optical devices including p-n junctions, MOS-capacitors, MOSFETs, optical waveguides, quantum-well lasers, light amplifiers, and metallo-dielectric light guides. Emphasis is on relationships between structure and physical properties. Elementary quantum and statistical mechanics concepts are used. Prerequisite: MATSCI 195/205 or equivalent. Undergraduates register for 199 for 4 units; graduates register for 209 for 3 units.
Same as: MATSCI 209

MATSCI 200. Master's Research. 1-15 Unit.
Participation in a research project.

MATSCI 201. Applied Quantum Mechanics I. 3 Units.
Emphasis is on applications in modern devices and systems. Topics include: Schrödinger's equation, eigenfunctions and eigenvalues, solutions of simple problems including quantum wells and tunneling, quantum harmonic oscillator, coherent states, operator approach to quantum mechanics, Dirac notation, angular momentum, hydrogen atom, calculation techniques including matrix diagonalization, perturbation theory, variational method, and time-dependent perturbation theory with applications to optical absorption, nonlinear optical coefficients, and Fermi's golden rule. Prerequisites: MATH 52 and 53, EE 65 or PHYSICS 65 (or PHYSICS 43 and 45).
Same as: EE 222

MATSCI 202. Materials Chemistry. 3-4 Units.
An introduction to the fundamental physical chemical principles underlying materials properties. Beginning from basic quantum chemistry, students will learn how the electronic configuration of molecules and solids impacts their structure, stability/reactivity, and spectra. Topics for the course include molecular symmetry, molecular orbital theory, solid-state chemistry, coordination compounds, and nanomaterials chemistry. Using both classroom lectures and journal discussions, students will gain an understanding of and be well-positioned to contribute to the frontiers of materials chemistry, ranging from solar-fuel generation to next-generation cancer treatments. Undergraduates register in 192 for 4 units; graduates register in 202 for 3 units.
Same as: MATSCI 192

MATSCI 203. Atomic Arrangements in Solids. 3-4 Units.
Atomic arrangements in perfect and imperfect solids, especially important metals, ceramics, and semiconductors. Elements of formal crystallography, including development of point groups and space groups. Undergraduates register in 193 for 4 units; graduates register in 203 for 3 units.
Same as: MATSCI 193

MATSCI 204. Thermodynamics and Phase Equilibria. 3 Units.
The principles of heterogeneous equilibria and their application to phase diagrams. Thermodynamics of solutions; chemical reactions; non-stoichiometry in compounds; first order phase transitions and metastability; thermodynamics of surfaces, elastic solids, dielectrics, and magnetic solids.Offered online for grad students in summer quarter, while an in-person course for grads and undergrads will be available in winter quarter 2019.

MATSCI 205. Waves and Diffraction in Solids. 3-4 Units.
The elementary principals of x-ray, vibrational, and electron waves in solids. Basic wave behavior including Fourier analysis, interference, diffraction, and polarization. Examples of wave systems, including electromagnetic waves from Maxwell's equations. Diffracted intensity in reciprocal space and experimental techniques such as electron and x-ray diffraction. Lattice vibrations in solids, including vibrational modes, dispersion relationship, density of states, and thermal properties. Free electron model. Basic quantum mechanics and statistical mechanics including Fermi-Dirac and Bose-Einstein statistics. Prerequisite: MATSCI 193/203 or consent of instructor. Undergraduates register for 195 for 4 units; graduates register for 205 for 3 units.
Same as: MATSCI 195, PHOTON 205

MATSCI 206. Defects in Crystalline Solids. 3-4 Units.
Thermodynamic and kinetic behaviors of 0-D (point), 1-D (line), and 2-D (interface and surface) defects in crystalline solids. Influences of these defects on the macroscopic ionic, electronic, and catalytic properties of materials, such as batteries, fuel cells, catalysts, and memory-storage devices. Undergraduates register for 196 for 4 units; graduates register for 206 for 3 units.
Same as: MATSCI 196

MATSCI 207. Rate Processes in Materials. 3-4 Units.
Diffusion and phase transformations in solids. Diffusion topics: Fick's laws, atomic theory of diffusion, and diffusion in alloys. Phase transformation topics: nucleation, growth, diffusional transformations, spinodal decomposition, and interface phenomena. Material builds on the mathematical, thermodynamic, and statistical mechanical foundations in the prerequisites. Prerequisites: MATSCI 194/204. Undergraduates register for 197 for 4 units; graduates register for 207 for 3 units.
Same as: MATSCI 197

MATSCI 208. Mechanical Properties of Materials. 3-4 Units.
Introduction to the mechanical behavior of solids, emphasizing the relationships between microstructure and mechanical properties. Elastic, anelastic, and plastic properties of materials. The relations between stress, strain, strain rate, and temperature for plastically deformable solids. Application of dislocation theory to strengthening mechanisms in crystalline solids. The phenomena of creep, fracture, and fatigue and their controlling mechanisms. Prerequisites: MATSCI 193/203. Undergraduates register for 198 for 4 units; graduates register for 208 for 3 units.
Same as: MATSCI 198

MATSCI 209. Electronic and Optical Properties of Solids. 3-4 Units.
The concepts of electronic energy bands and transports applied to metals, semiconductors, and insulators. The behavior of electronic and optical devices including p-n junctions, MOS-capacitors, MOSFETs, optical waveguides, quantum-well lasers, light amplifiers, and metallo-dielectric light guides. Emphasis is on relationships between structure and physical properties. Elementary quantum and statistical mechanics concepts are used. Prerequisite: MATSCI 195/205 or equivalent. Undergraduates register for 199 for 4 units; graduates register for 209 for 3 units.
Same as: MATSCI 199

MATSCI 210. Organic and Biological Materials. 3-4 Units.
Unique physical and chemical properties of organic materials and their uses. The relationship between structure and physical properties, and techniques to determine chemical structure and molecular ordering. Examples include liquid crystals, dendrimers, carbon nanotubes, hydrogels, and biopolymers such as lipids, protein, and DNA. Prerequisite: Thermodynamics and ENGR 50 or equivalent. Undergraduates register for 190 for 4 units; graduates register for 210 for 3 units.
Same as: MATSCI 190

MATSCI 213. Microstructure in Materials. 3 Units.
Defects and Disorder in materials based on the recommendations from the discussions over the past few months. Please let me know if this is ok for now. nnOverview of defects and disorder across crystalline and amorphous or glassy phases that are central to function and application, spanning metals, ceramics, and soft/biological matter. Structure and properties of simple 0D/1D/2D defects in crystalline materials. Scaling laws, connectivity and frustration, and hierarchy/distributions of structure across length scales in more disordered materials. Key characterization techniques.n nPre-reqs: MATSCI 211 (thermo), 212 (kinetics).

MATSCI 214. Structure and Bonding. 3 Units.
Chemical foundations of materials science concerning structure and bonding from a physical and solid-state chemistry perspective. Topics include quantum chemistry; molecular structure, symmetry, and spectroscopy; bonding in molecular orbital, crystal field, and ligand field theories; coordination compounds; chemistry of solid-state metallic, covalent, and ionic materials; introductory defect chemistry; and links to the electronic, optical, and magnetic properties of solid state, polymer, and nanoscale materials.

MATSCI 225. Biochips and Medical Imaging. 3 Units.
The course covers state-of-the-art and emerging bio-sensors, bio-chips, imaging modalities, and nano-therapies which will be studied in the context of human physiology including the nervous system, circulatory system and immune system. Medical diagnostics will be divided into bio-chips (in-vitro diagnostics) and medical and molecular imaging (in-vivo imaging). In-depth discussion on cancer and cardiovascular diseases and the role of diagnostics and nano-therapies.
Same as: EE 225, SBIO 225

MATSCI 230. Materials Science Colloquium. 1 Unit.
May be repeated for credit.

MATSCI 241. Mechanical Behavior of Nanomaterials. 3 Units.
Mechanical behavior of the following nanoscale solids: 2D materials (metal thin films, graphene), 1D materials (nanowires, carbon nanotubes), and 0D materials (metallic nanoparticles, quantum dots). This course will cover elasticity, plasticity and fracture in nanomaterials, defect-scarce nanomaterials, deformation near free surfaces, coupled optoelectronic and mechanical properties (e.g. piezoelectric nanowires, quantum dots), and nanomechanical measurement techniques. Prerequisites: Mechanics of Materials (ME80) or equivalent.
Same as: ME 241

MATSCI 250. Introduction to Materials Science, Biomaterials Emphasis. 3 Units.
Topics include: the relationship between atomic structure and macroscopic properties of man-made and natural materials; mechanical and thermodynamic behavior of surgical implants including alloys, ceramics, and polymers; and materials selection for biotechnology applications such as contact lenses, artificial joints, and cardiovascular stents. No prerequisite.
Same as: ONLINE ONLY

MATSCI 251. Microstructure and Mechanical Properties. 3-4 Units.
Primarily for students without a materials background. Mechanical properties and their dependence on microstructure in a range of engineering materials. Elementary deformation and fracture concepts, strengthening and toughening strategies in metals and ceramics. Topics: dislocation theory, mechanisms of hardening and toughening, fracture, fatigue, and high-temperature creep. Undergraduates register in 151 for 4 units; graduates register for 251 in 3 units.
Same as: MATSCI 151

MATSCI 256. Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution. 3-4 Units.
Operating principles and applications of emerging technological solutions to the energy demands of the world. The scale of global energy usage and requirements for possible solutions. Basic physics and chemistry of solar cells, fuel cells, and batteries. Performance issues, including economics, from the ideal device to the installed system. The promise of materials research for providing next generation solutions.

MATSCI 299. Practical Training. 1 Unit.
Educational opportunities in high-technology research and development labs in industry. Qualified graduate students engage in internship work and integrate that work into their academic program. Following the internship, students complete a research report outlining their work activity, problems investigated, key results, and any follow-on projects they expect to perform. Student is responsible for arranging own employment. See department student services manager before enrolling.

MATSCI 300. Ph.D. Research. 1-15 Unit.
Participation in a research project.

MATSCI 301. Engineering Energy Policy Change. 2 Units.
Public policy and economic decisions profoundly affect all aspects of the energy ecosystem, including its supply, distribution, storage and utilization. These decisions can also influence the pace and focus of innovation of new technologies, including through government-funded research and development programs or regulatory efforts. This course will equip graduate students, who have strong science and engineering backgrounds, with a basic ability to understand and shape the ideation and implementation of sound energy and, related economic, policy. Building on case studies of both aspirational and reactive U.S. energy policy-making, students will design their own policy proposals for new, ambitious and achievable moonshot goals that advance a sustainable and prosperous future. In particular, students will choose a moonshot goal designed to reduce U.S. (and/or global) transportation-related emissions. These proposals may focus on specific mobility technologies (e.g., new zero-GHG liquid fuels), lead to transformation of mobility systems (e.g., integration of wide-scale automation into the transportation sector), or reduce emissions in another way altogether (e.g., moving manufacturing closer to consumption through 3-d printing). Students will also be introduced to gunshot scenarios, moments of energy crisis that require robust response and can create openings for dramatic change to the energy ecosystem.

MATSCI 302. Solar Cells. 3 Units.
In the last 15 years, the solar power market has grown in size by 100 times while solar modules prices have fallen by 20 times. Unsubsidized, solar power projects now compete favorably against fossil fuels in many countries and is on track to be the largest energy provider in the future. How did this happen? nnIn MatSci 302 we will take a comprehensive look at solar cells starting from the underlying device physics that are relevant to all photovoltaic cell technologies. We will then look at the undisputed king (silicon based solar cells); how do they work today and how will they develop in the future. Finally, we will look at why past challengers have failed and how future challengers can succeed. This class will be co-taught by Brian and Craig, who graduated from the Material Science PhD program in 2011 and then started PLANT PV, a startup that developed a solar technology from idea to protoype and then full implementation on production lines in China. The lecturers routinely visit manufacturing facilities in Asia and work closely with engineering staff at the largest solar cell makers in the world to implement their technology into production lines.

MATSCI 303. Principles, Materials and Devices of Batteries. 3 Units.
Thermodynamics and electrochemistry for batteries. Emphasis on lithium ion batteries, but also different types including lead acid, nickel metal hydride, metal air, sodium sulfur and redox flow. Battery electrode materials, electrolytes, separators, additives and electrode-electrolyte interface. Electrochemical techniques; advanced battery materials with nanotechnology; battery device structure. Prerequisites: undergraduate chemistry.

MATSCI 310. Statistical Mechanics for Materials & Materials Chemistry. 3-4 Units.
This course will cover how thermodynamics evolves from statistical mechanics, with a specific emphasis placed on quantum materials. It will cover distributions for quantum particles, diffusion and aggregation, and a basic discussion of characterizing phase transitions. If time permits, selected topics in quantum information theory will be discussed. Undergraduates register for 4 units; graduates register for 3 units.

MATSCI 312. New Methods in Thin Film Synthesis. 3 Units.
Materials base for engineering new classes of coatings and devices. Techniques to grow thin films at atomic scale and to fabricate multilayers/superlattices at nanoscale. Vacuum growth techniques including evaporation, molecular beam epitaxy (MBE), sputtering, ion beam assisted deposition, laser ablation, chemical vapor deposition (CVD), and electroplating. Future direction of material synthesis such as nanocluster deposition and nanoparticles self-assembly. Relationships between deposition parameters and film properties. Applications of thin film synthesis in microelectronics, nanotechnology, and biology. SCPD offering.

MATSCI 316. Nanoscale Science, Engineering, and Technology. 3 Units.
This course covers important aspects of nanotechnology in nanomaterials synthesis and fabrication, novel property at the nanoscale, tools and applications: a variety of nanostructures including nanocrystal, nanowire, carbon nanotube, graphene, nanoporous material, block copolymer, and self-assembled monolayer; nanofabrication techniques developed over the past 20 years; thermodynamic, electronic and optical property; applications in solar cells, batteries, biosensors and electronics. Other nanotechnology topics may be explored through a group project. SCPD offering.

MATSCI 320. Nanocharacterization of Materials. 3 Units.
Current methods of directly examining the microstructure of materials. Topics: optical microscopy, scanning electron and focused ion beam microscopy, field ion microscopy, transmission electron microscopy, scanning probe microscopy, and microanalytical surface science methods. Emphasis is on the electron-optical techniques. Recommended: 193/203.

MATSCI 321. Transmission Electron Microscopy. 3 Units.
Image formation and interpretation. The contrast phenomena associated with perfect and imperfect crystals from a physical point of view and from a formal treatment of electron diffraction theory. The importance of electron diffraction to systematic analysis and recent imaging developments. Recommended: 193/203, 195/205, or equivalent.

MATSCI 322. Transmission Electron Microscopy Laboratory. 3 Units.
Practical techniques in transmission electron microscopy (TEM): topics include microscope operation and alignment, diffraction modes and analysis, bright-field/dark-field imaging, high resolution and aberration corrected imaging, scanning TEM (STEM) imaging, x-ray energy dispersive spectrometry (EDS) and electron energy loss spectrometry (EELS) for compositional analysis and mapping. Prerequisite: 321, consent of instructor. Enrollment limited to 12.

MATSCI 323. Thin Film and Interface Microanalysis. 3 Units.
The science and technology of microanalytical techniques will be discussed. We consider ways to characterize the structural, compositional, morphological, electronic, optical, mechanical, and magnetic properties of surfaces and interfaces. We will talk about different types of surface analytical techniques that rely on the use of electrons, photons, ions, and sharp tips to learn about different aspects about surfaces. We also discuss strategies on how to combine such techniques to gain a more complete and quantitative picture of a surface. We will also describe the inner workings and design of the hardware involved in analyzing surfaces.n*Prerequisite: some prior exposure to atomic and electronic structure of solids.

MATSCI 326. X-Ray Science and Techniques. 3 Units.
This course provides an introduction to how x-rays interact with matter and how x-ray techniques can be used for developing new understanding of the properties of materials. Course topics include diffraction from ordered and disordered materials, x-ray absorption/ emission spectroscopy, photoemission, and coherent scattering. Sources including synchrotrons and x-ray lasers and an introduction to time-resolved techniques. This course includes a parallel laboratory effort in which students will have an opportunity to carry out experiments at the Stanford Synchrotron Radiation Lightsource at the SLAC National Accelerator Laboratory.
Same as: PHOTON 326

MATSCI 331. Atom-based computational methods for materials. 3 Units.
Introduction to atom-based computational methods for materials with emphasis on quantum methods. Topics include density functional theory, tight-binding and empirical approaches. Computation of optical, electronic, phonon properties. Bulk materials, interfaces, nanostructures. Molecular dynamics. Prerequisites - undergraduate quantum mechanics.

MATSCI 341. Quantum Theory of Electronic and Optical Excitations in Materials. 3 Units.
Introduction to the fundamentals of solid-state physics and materials science, with emphasis in electronic and optical excitation processes. We will develop quantum formalisms to understand concepts including: elementary excitations in materials, crystal symmetry and Bloch¿s theorem, electronic bandstructure and methods to compute it (including tight-binding and density-functional theory), linear response theory, dielectric functions, as well as electronic transitions and optical properties of solids. We apply these methods to understand the electronic and optical properties of real materials, including bulk metals, semiconductors, and 2D materials.

MATSCI 343. Organic Semiconductors for Electronics and Photonics. 3 Units.
The science of organic semiconductors and their use in electronic and photonic devices. Topics: methods for fabricating thin films and devices; relationship between chemical structure and molecular packing on properties such as band gap, charge carrier mobility and luminescence efficiency; doping; field-effect transistors; light-emitting diodes; lasers; biosensors; photodetectors and photovoltaic cells.

MATSCI 346. Nanophotonics. 3 Units.
Recent developments in micro- and nanophotonic materials and devices. Basic concepts of photonic crystals. Integrated photonic circuits. Photonic crystal fibers. Superprism effects. Optical properties of metallic nanostructures. Sub-wavelength phenomena and plasmonic excitations. Meta-materials. Prerequisite: Electromagnetic theory at the level of 242.
Same as: EE 336

MATSCI 347. Magnetic materials in nanotechnology, sensing, and energy. 3 Units.
This course will teach the fundamentals of magnetism, magnetic mateirals, and magnetic nanostructures and their myriad of applications in nanotechnology, sensing, energy and related areas. The scope of the course include: atomic origins of magnetic moments, magnetic exchange and ferromagnetism, types of magnetic order, magnetic anisotropy, domains, domain walls, hysteresis loops, hard and soft magnetic materials, demagnetization factors, magnetic nanoparticles and nanostructures, spintronics, and multiferroics. The key applications include electromagnet and permanent magnet, magnetic inductors, magnetic sensors, magnetic memory, hard disk drives, energy generation and harvesting, biomagnetism, etc. Prerequisites: College level electricity and magnetism course or equivalent.

MATSCI 358. Fracture and Fatigue of Materials and Thin Film Structures. 3 Units.
Linear-elastic and elastic-plastic fracture mechanics from a materials science perspective, emphasizing microstructure and the micromechanisms of fracture. Plane strain fracture toughness and resistance curve behavior. Mechanisms of failure associated with cohesion and adhesion in bulk materials, composites, and thin film structures. Fracture mechanics approaches to toughening and subcritical crack-growth processes, with examples and applications involving cyclic fatigue and environmentally assisted subcritical crack growth. Prerequisite: 151/251, 198/208, or equivalent. SCPD offering.
Same as: ME 258

MATSCI 380. Nano-Biotechnology. 3 Units.
Literature based. Principles that make nanoscale materials unique, applications to biology, and how biological systems can create nanomaterials. Molecular sensing, drug delivery, bio-inspired synthesis, self-assembling systems, and nanomaterial based therapies. Interactions at the nanoscale. Applications and opportunities for new technology.

MATSCI 381. Biomaterials in Regenerative Medicine. 3 Units.
Materials design and engineering for regenerative medicine. How materials interact with cells through their micro- and nanostructure, mechanical properties, degradation characteristics, surface chemistry, and biochemistry. Examples include novel materials for drug and gene delivery, materials for stem cell proliferation and differentiation, and tissue engineering scaffolds. Prerequisites: undergraduate chemistry, and cell/molecular biology or biochemistry.
Same as: BIOE 361

MATSCI 384. Materials Advances for Neurotechnology: Materials Meet the Mind. 3 Units.
The dichotomy between the material world and the mental world has driven the curiosity of scientists to explore the wonders of the brain, as well as motivated the continued innovations of novel technologies based on advances in materials science and engineering to understand the brain. This course introduces the basic principles of materials design and fabrication for probing the inner workings of the brain, discusses the fundamental challenges of state-of-the-art neurotechnologies, and explores the latest breakthroughs in materials-assisted neuroengineering. The course will cover the following topics: fundamentals of electrophysiology of the nervous system, mechanical and biochemical requirements of neural interfacing materials, materials for electrical neural interfaces (tungsten/carbon electrodes, Utah/Michigan/ECoG electrode arrays), materials for optical neural interfaces (optical fibers/waveguides for optogenetics, microprisms/GRIN lenses for fluorescence imaging of neural activity), and materials for biochemical neural interfaces (implantable microfluidic probes, neurotrophic scaffolds). Students will be able to speak the languages of both materials science and neuroengineering and acquire the knowledge and skills to understand and address pressing neuroscience challenges with materials advances. This course will include lectures, student discussions/presentations and guest lectures given by pioneers in related fields at Stanford and other schools/companies in the local area. nPrerequisite: undergraduate physics and chemistry; MATSCI 152, 158, 164, 190 or equivalents are recommended but not required prior to taking this course.

MATSCI 385. Biomaterials for Drug Delivery. 3 Units.
Fundamental concepts in engineering materials for drug delivery. The human body is a highly interconnected network of different tissues and there are all sorts of barriers to getting pharmaceutical drugs to the right place at the right time. Topics include drug delivery mechanisms (passive, targeted), therapeutic modalities and mechanisms of action, engineering principles of controlled release and quantitative understanding of drug transport, chemical and physical characteristics of delivery molecules and assemblies, significance of biodistribution and pharmacokinetic models, toxicity of biomaterials and drugs, and immune responses.
Same as: BIOE 385

MATSCI 399. Graduate Independent Study. 1-10 Unit.
Under supervision of a faculty member.

MATSCI 400. Participation in Materials Science Teaching. 1-3 Unit.
May be repeated for credit.

MATSCI 801. TGR Project for MS Students. 0 Units.
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MATSCI 802. TGR Dissertation for Ph.D Students. 0 Units.
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