EMSE (EMSE)

EMSE 110. Transitioning Ideas to Reality I - Materials in Service of Industry and Society. 1 Unit.
In order for ideas to impact the lives of individuals and society they must be moved from "blue sky" to that which is manufacturable. Therein lies true creativity - design under constraint. Greater Cleveland is fortunate to have a diverse set of industries that serve medical, aerospace, electric, and advanced-materials technologies. This course involves trips to an array of work sites of leading companies to witness first-hand the processes and products, and to interact directly with practitioners. Occasional in-class speakers with demonstrations will be used when it is not logistically reasonable to visit off-site.

EMSE 120. Transitioning Ideas to Reality II - Manufacturing Laboratory. 2 Units.
This course complements EMSE 110. In that class students witness a diverse array of processing on-site in industry. In this class students work in teams and as individuals within processing laboratories working with an array of "real materials" to explore the potential of casting, machining, and deformation processes to produce real parts and/or components. An introduction to CAD as a means of communication is provided. The bulk of the term is spent in labs doing hands-on work. Planned work is carried out to demonstrate techniques and potential. Students have the opportunity to work independently or in teams to produce articles as varied as jewelry, electronics, transportation vehicles, or novel components or devices of the students' choosing.

EMSE 125. Freshman Research in Materials Science and Engineering. 1 Unit.
Freshman students conduct independent research in the area of material science and engineering, working closely with graduate student(s) and/or postdoctoral fellow(s), and supervised by an EMSE faculty member. An average of 5-6 hr/wk in the laboratory, periodic updates, and an end of semester report is required. Prereq: Limited to freshman, with permission of instructor.

EMSE 220. Materials Laboratory I. 2 Units.

EMSE 228. Mathematical and Computational Methods for Materials Science and Engineering. 3 Units.
The course combines fundamental topics of material science and engineering with underlying mathematical methods and coding for computation. Focusing on the mathematics of vectors and using Mathematica as computational framework, the course teaches how to solve problems drawn from crystallography, diffraction, imaging of materials, and image processing. Students will develop a fundamental understanding of the basis for solving these problems including understanding the constituent equations, solution methods, and analysis and presentation of results. Prereq: (ENGR 131 or EECS 132) and ENGR 145

EMSE 276. Materials Properties and Design. 3 Units.
Relation of crystal structure, microstructure, and chemical composition to the properties of materials. The role of materials processing in controlling structure so as to obtain desired properties, using examples from metals, ceramics, semiconductors, and polymers. Design concept includes exercises in materials selection, and in design of materials to meet specified performance requirements. Prereq: MATH 121 and ENGR 145. Prereq or Coreq: PHYS 122 or PHYS 124.

EMSE 308. Welding Metallurgy. 3 Units.
Introduction to arc welding and metallurgy of welding. The course provides a broad overview of different industrial applications requiring welding, the variables controlling critical property requirements of the weld and a survey of the different types of arc welding processes. The course details the fundamental concepts that govern the different aspects of arc welding including the welding arc; weld pool solidification, precipitate formation and solid state phase transformations. Offered as EMSE 308 and EMSE 408. Coreq: EMSE 327.

EMSE 319. Processing and Manufacturing of Materials. 3 Units.
Introduction to processing technologies by which materials are manufactured into engineering components. Discussion of how processing methods are dependent on desired composition, structure, microstructure, and defects, and how processing affects material performance. Emphasis will be placed on processes and treatments to achieve or improve chemical, mechanical, physical performance and/or aesthetics, including: casting, welding, forging, cold-forming, powder processing of metals and ceramics, and polymer and composite processing. Coverage of statistics and computational tools relevant to materials manufacturing. Prereq: EMSE 276.

EMSE 320. Materials Laboratory II. 1 Unit.
Measurement of thermophysical properties of materials emphasizing thermal and electrical properties of materials. Laboratory teams are selected for all experiments. Statistical analysis of experimental results also emphasized. Recommended preparation or corequisite: EMSE 276.

EMSE 325. Undergraduate Research in Materials Science and Engineering. 1 - 3 Units.
Undergraduate laboratory research in materials science and engineering. Students will undertake an independent research project alongside graduate student(s) and/or postdoctoral fellow(s), and will be supervised by an EMSE faculty member. Written and oral reports will be given on a regular basis, and an end of semester report is required. The course can be repeated up to four (4) times for a total of six (6) credit hours. Prereq: Sophomore or Junior standing and consent of instructor.

EMSE 327. Thermodynamic Stability and Rate Processes. 3 Units.
An introduction to thermodynamics of materials as applied to metals, ceramics, polymers and optical/radiant heat transfer for photovoltaics. The laws of thermodynamics are introduced and the general approaches used in the thermodynamic method are presented. Systems studied span phase stability and oxidation in metals and oxides; nitride ceramics and semiconductors; polymerization, crystallization and block copolymer domain formation; and the thermodynamics of systems such as for solar power collection and conversion. Recommended preparation: EMSE 228 and ENGR 225 or equivalent. Prereq: EMSE 276 or EMSE 201.
EMSE 328. Mesoscale Structural Control of Functional Materials. 3 Units.
The course focuses on mesoscale structure of materials and their interrelated effects on properties, mostly in electrical in nature. The mesoscale science covers the structures varying from electronic- to micro-structure. In each scale, fundamental science will be complemented by examples of applications and how the structure is exploited both to modify and enable function. The student will develop an understanding of how the structure across multiple scales are interrelated and how to tailor them for desired outcomes. Offered as: EMSE 328 and EMSE 428. Prereq: (MATH 223 or MATH 227) and (EMSE 276 or EMSE 201).

EMSE 330. Materials Laboratory III. 2 Units.

EMSE 335. Strategic Metals and Materials for the 21st Century. 3 Units.
This course seeks to create an understanding of the role of mineral-based materials in the modern economy focusing on how such knowledge can and should be used in making strategic choices in an engineering context. The history of the role of materials in emerging technologies from a historical perspective will be briefly explored. The current literature will be used to demonstrate the connectedness of materials availability and the development and sustainability of engineering advances with examples of applications exploiting structural, electronic, optical, magnetic, and energy conversion properties. Processing will be comprehensively reviewed from source through refinement through processing including property development through application of an illustrative set of engineering materials representing commodities, less common metals, and minor metals. The concept of strategic recycling, including design for recycling and waste stream management will be considered. Offered as EMSE 335 and EMSE 435. Prereq: Senior standing or graduate student.

EMSE 343. Processing of Electronic Materials. 3 Units.
The class will focus on the processing of materials for electronic applications. Necessary background into the fundamentals and applications will be given at the beginning to provide the basis for choices made during processing. MOSFET will be used as the target application. However, the processing steps covered are related to many other semiconductor based applications. The class will include both planar and bulk processing. Offered as: EMSE 343 and EMSE 443. Prereq: (PHYS 122 or PHYS 124) and EMSE 276.

EMSE 345. Materials for Biological and Medical Technology. 3 Units.
A survey of natural biomaterials and synthetic biomedical materials from the perspective of materials science and engineering, focusing on how processing/synthesis, structure, and properties determine materials performance. Structure and properties of bones and teeth, soft tissue, and cartilage. Introduction to properties and applications of materials for medical technologies, such as orthopedic implants, sensors, transducers, and materials for biomedical imaging and drug delivery. Selected case studies. Biomimetics as a design strategy for synthetic materials. Prereq: ENGR 200 and (ENGR 145 or EMSE 146).

EMSE 349. Materials for Energy and Sustainability. 3 Units.
Levels and categories of energy usage in the U.S. and the world. Availability of raw materials, including strategic materials; factors affecting global reserves and annual world production. Design strategies, and how the inclusion of environmental impacts as design criteria can alter materials selections. Resource demand (energy and water) of materials production, fabrication, and recycling. Roles of engineered materials in renewable or advanced energy technologies: photovoltaics, fuel cells, wind, batteries, capacitors, thermoelectrics. Energy harvesting. Role of magnetic materials in energy technology. Materials in energy-efficient lighting. Energy return on energy invested. Semester projects will enable students to explore related topics (e.g. geothermal; biomass; solar thermal; advances in energy-efficient manufacturing) in greater depth. Offered as EMSE 349 and EMSE 449. Prereq: ENGR 225 and ENGR 145 and (PHYS 122 or PHYS 124) or Requisites Not Met permission.

EMSE 365. Surface Engineering of Materials. 3 Units.
Introduction to surface engineering of materials, understood as a treatment that allows the surface to perform functions different from those performed by the bulk. This may include engineering the mechanical, chemical, electrical, magnetic, or optical properties of the surface and near-surface regions for specific applications. For a variety of technologically important classes of materials, the course reviews general concepts of surface engineering, the underlying physical and materials science principles, technical implementations, and typical applications. Recommended for graduate students and advanced undergraduate students. Offered as EMSE 365 and EMSE 465. Prereq: (EMSE 276 and ENGR 225) or Requisites Not Met permission.

EMSE 368. Scientific Writing in Materials Science and Engineering. 3 Units.
For writing a thesis (or a publication) in the field of materials science and engineering, students need a diverse set of skills in addition to mastering the scientific content. Generally, scientific writing requires proficiency in document organization, professional presentation of numerical and graphical data, literature retrieval and management, text processing, version control, graphical illustration, mathematical typesetting, the English language, elements of style, etc. Scientific writing in materials science and engineering, specifically, requires additional knowledge about e.g. conventions of numerical precision, error limits, mathematical typesetting, proper use of units, proper digital processing of micrographs, etc. Having to acquire these essential skills at the beginning of thesis (or publication) writing may compromise the outcome by distracting from the most important task of composing the best possible scientific content. This course properly prepares students for scientific writing with a comprehensive spectrum of knowledge, skills, and tools enabling them to fully focus on the scientific content of their thesis or publication when the time has come to start writing. Similar to artistic drawing, where the ability to “see” is as (or more) important as skills of the hand, the ability of proper scientific writing is intimately linked to the ability of critically reviewing scientific texts. Therefore, students will practice both authoring and critical reviewing of material science texts. To sharpen students’ skills of reviewing, examples of good and less good scientific writing will be taken from published literature of materials science and engineering and analyzed in the context of knowledge acquired in the course. At the end of the course, students will have set up skills and a highly functional work environment to start writing their role thesis or article with full focus on the scientific content. While the course mainly targets students of materials science and engineering, students of other disciplines of science and engineering may also benefit from the course material. Offered as EMSE 368 and EMSE 468.
EMSE 372. Structural Materials by Design. 4 Units.

EMSE 379. Design for Lifetime Performance. 3 Units.

EMSE 396. Special Project or Thesis. 1 - 18 Units.
Special research projects or undergraduate thesis in selected material areas.

EMSE 398. Senior Project in Materials I. 1 Unit.
Independent Research project. Projects selected from those suggested by faculty; usually entail original research. The EMSE 398 and 399 sequence form an approved SAGES capstone. Counts as SAGES Senior Capstone.

EMSE 399. Senior Project in Materials II. 2 Units.
Independent Research project. Projects selected from those suggested by faculty; usually entail original research. Requirements include periodic reporting of progress, plus a final oral presentation and written report. Counts as SAGES Senior Capstone. Prereq: EMSE 398.

EMSE 400T. Graduate Teaching I. 0 Unit.
To provide teaching experience for all Ph.D.-bound graduate students. This will include preparing exams/quizzes, homework, leading recitation sessions, tutoring, providing laboratory assistance, and developing teaching aids that include both web-based and classroom materials. Graduate students will meet with supervising faculty member throughout the semester. Grading is pass/fail. Students must receive three passing grades and up to two assignments may be taken concurrently. Recommended preparation: Ph.D. student in Materials Science and Engineering.

EMSE 405. Dielectric and Electrical Properties of Materials. 3 Units.

EMSE 408. Welding Metallurgy. 3 Units.
Introduction to arc welding and metallurgy of welding. The course provides a broad overview of different industrial applications requiring welding, the variables controlling critical property requirements of the weld and a survey of the different types of arc welding processes. The course details the fundamental concepts that govern the different aspects of arc welding including the welding arc, weld pool solidification, precipitate formation and solid state phase transformations. Offered as EMSE 308 and EMSE 408.

EMSE 409. Deformation Processing. 3 Units.
Flow stress as a function of material and processing parameters; yielding criteria; stress states in elastic-plastic deformation; forming methods: forging, rolling, extrusion, drawing, stretch forming, composite forming.

EMSE 413. Fundamentals of Materials Engineering and Science. 3 Units.
Provides a background in materials for graduate students with undergraduate majors in other branches of engineering and science: reviews basic bonding relations, structure, and defects in crystals. Lattice dynamics; thermodynamic relations in multi-component systems; microstructural control in metals and ceramics; mechanical and chemical properties of materials as affected by structure; control of properties by techniques involving structure property relations; basic electrical, magnetic and optical properties.

EMSE 414. Electrical, Magnetic, Optical, and Thermal Properties of Materials. 3 Units.
Reviews quantum mechanics as applied to materials, energy bands, and density of states; Electrical properties of metals, semiconductors, insulators, and superconductors; Optical properties of materials, including: metallic luster, color, and optoelectronics; Magnetic properties of materials, including: Types of magnetic behavior, theory, and applications; Thermal properties of materials, including: heat capacity, thermal expansion, and thermal conductivity. Prereq: Graduate Standing in Materials Science and Engineering or Requisites Not Met permission.

EMSE 417. Properties of Materials in Extreme Environments. 3 Units.
Fundamentals of degradation pathways of materials under extreme conditions; thermodynamic stability of microstructures, deformation mechanisms, and failure mechanisms. Extreme conditions that will typically be addressed include: elevated temperatures, high-strain rates (ballistic), environmental effects, nuclear radiation, and small scales. Examples will be drawn from recent events as appropriate.

EMSE 421. Fracture of Materials. 3 Units.
EMSE 422. Failure Analysis. 3 Units.
Methods and procedures for determining the basic causes of failures in structures and components. Recognition of fractures and excessive deformations in terms of their nature and origin. Development and full characterization of fractures. Review of essential mechanical behavior concepts and fracture mechanics concepts applied to failure analyses in inorganic, organic, and composite systems. Legal, ethical, and professional aspects of failures from service. Prereq: EMSE 372 or EMAE 372 or Requisites Not Met permission.

EMSE 427. Defects in Solids. 3 Units.
Defects in solids control many properties of interest to the materials scientist or engineer. This course focuses on point, line, and interfacial defects in crystals and their interactions, including calculations of defect energies and interaction forces. Crystallographic defects presented include point defects (e.g., vacancies, interstitials, substitutional and interstitial impurities), line defects (e.g., dislocations), and planar defects (e.g., grain boundaries). The consequence of point defects on diffusion as well as on optical and electronic properties is discussed. Dislocation motion and dislocation dissociation are treated, and the influence of dislocation dynamics on yield phenomena, work hardening, and other mechanical properties are discussed. The role of grain boundaries and inter-phase boundaries in determining the physical properties of the material are presented. Experimental techniques for characterizing defects are integrated throughout the course. Recommended preparation: MATH 223 (or equivalent) and EMSE 276 (or equivalent).

EMSE 428. Mesoscale Structural Control of Functional Materials. 3 Units.
The course focuses on mesoscale structure of materials and their interrelated effects on properties, mostly in electrical nature. The mesoscale science covers the structures varying from electronic- to micro-structure. In each scale, fundamental science will be complimented by examples of applications and how the structure is exploited both to modify and enable function. The student will develop an understanding of how the structure across multiple scales are interrelated and how to tailor them for desired outcomes. Offered as: EMSE 328 and EMSE 428.

EMSE 430. Additive Manufacturing of Metals, Polymers, and Ceramics. 3 Units.
Additive manufacturing, though rooted in well-established unit operations, has emerged as a distinctive approach to the production of components and assemblies. This course will cover the conceptual approach, its history, the current state of the art, and analysis of projections of it future role. The respective advances in digital description of parts and digital control of processes will be described as machine design and construction. The emphasis, however, will be on the processing-structure-property relationships. Polymers, metals, and ceramics will be treated separately and contrasted. The course will make extensive use of current literature. Prereq: EMSE 276 or Requisites Not Met permission.

EMSE 435. Strategic Metals and Materials for the 21st Century. 3 Units.
This course seeks to create an understanding of the role of mineral-based materials in the modern economy focusing on how such knowledge can and should be used in making strategic choices in an engineering context. The history of the role of materials in emerging technologies from a historical perspective will be briefly explored. The current literature will be used to demonstrate the connectedness of materials availability and the development and sustainability of engineering advances with examples of applications exploiting structural, electronic, optical, magnetic, and energy conversion properties. Processing will be comprehensively reviewed from source through refinement through processing including property development through application of an illustrative set of engineering materials representing commodities, less common metals, and minor metals. The concept of strategic recycling, including design for recycling and waste stream management will be considered. Offered as EMSE 335 and EMSE 435. Prereq: Senior standing or graduate student.

EMSE 443. Processing of Electronic Materials. 3 Units.
The class will focus on the processing of materials for electronic applications. Necessary background into the fundamentals and applications will be given at the beginning to provide the basis for choices made during processing. MOSFET will be used as the target application. However, the processing steps covered are related to many other semiconductor based applications. The class will include both planar and bulk processing. Offered as: EMSE 343 and EMSE 443. Prereq: PHYS 122 or PHYS 124 and EMSE 276.

EMSE 449. Materials for Energy and Sustainability. 3 Units.
Levels and categories of energy usage in the U.S. and the world. Availability of raw materials, including strategic materials; factors affecting global reserves and annual world production. Design strategies, and how the inclusion of environmental impacts as design criteria can alter materials selections. Resource demand (energy and water) of materials production, fabrication, and recycling. Roles of engineered materials in renewable or advanced energy technologies: photovoltaics, fuel cells, wind, batteries, capacitors, thermoelectrics. Energy harvesting. Role of magnetic materials in energy technology. Materials in energy-efficient lighting. Energy return on energy invested. Semester projects will enable students to explore related topics (e.g. geothermal; biomass; solar thermal; advances in energy-efficient manufacturing) in greater depth. Offered as EMSE 349 and EMSE 449. Prereq: ENGR 225 and (ENGR 145 or EMSE 146) and (PHYS 122 or PHYS 124) or requisites not met permission.

EMSE 463. Magnetism and Magnetic Materials. 3 Units.
This course covers the fundamentals of magnetism and application of modern magnetic materials especially for energy and data storage technologies. The course will focus on intrinsic and extrinsic magnetic properties, processing of magnetic materials to achieve important magnetic performance metrics, and the state-of-the-art magnetic materials used today. The topics related to intrinsic properties, include: magnetic dipole moments, magnetization, exchange coupling, magnetic anisotropy and magnetostriiction. Topics related to extrinsic properties, include: magnetic hysteresis, frequency dependent magnetic response and magnetic losses. Technologically important permanent magnets (including rare earth containing alloys and magnetic oxides), soft magnets (including electrical steels, amorphous, ferrites, and nanocrystalline alloys), and thin film materials (including iron platinum) will be discussed in the context of their technological interest. Throughout the course, experimental techniques and data analysis will be discussed. The course is suitable for most graduate students and advanced undergraduates in engineering and science.
EMSE 465. Surface Engineering of Materials. 3 Units.
Introduction to surface engineering of materials, understood as a treatment that allows the surface to perform functions different from those performed by the bulk. This may include engineering the mechanical, chemical, electrical, magnetic, or optical properties of the surface and near-surface regions for specific applications. For a variety of technologically important classes of materials, the course reviews general concepts of surface engineering, the underlying physical and materials science principles, technical implementations, and typical applications. Recommended for graduate students and advanced undergraduate students. Offered as EMSE 365 and EMSE 465.

EMSE 468. Scientific Writing in Materials Science and Engineering. 3 Units.
For writing a thesis (or a publication) in the field of materials science and engineering, students need a diverse set of skills in addition to mastering the scientific content. Generally, scientific writing requires proficiency in document organization, professional presentation of numerical and graphical data, literature retrieval and management, text processing, version control, graphical illustration, mathematical typesetting, the English language, elements of style, etc. Scientific writing in materials science and engineering, specifically, requires additional knowledge about e.g. conventions of numerical precision, error limits, mathematical typesetting, proper use of units, proper digital processing of micrographs, etc. Having to acquire these essential skills at the beginning of thesis (or publication) writing may compromise the outcome by distracting from the most important task of composing the best possible scientific content. This course properly prepares students for scientific writing with a comprehensive spectrum of knowledge, skills, and tools enabling them to fully focus on the scientific content of their thesis or publication when the time has come to start writing. Similar to artistic drawing, where the ability to "see" is as (or more!) important as skills of the hand, the ability of proper scientific writing is intimately linked to the ability of critically reviewing scientific texts. Therefore, students will practice both authoring and critical reviewing of material science texts. To sharpen students’ skills of reviewing, examples of good and less good scientific writing will be taken from published literature of materials science and engineering and analyzed in the context of knowledge acquired in the course. At the end of the course, students will have set up skills and a highly functional work environment to start writing their role thesis or article with full focus on the scientific content. While the course mainly targets students of materials science and engineering, students of other disciplines of science and engineering may also benefit from the course material. Offered as EMSE 368 and EMSE 468.

EMSE 499. Materials Science and Engineering Colloquium. 0 - 1 Units.
Invited speakers deliver lectures on topics of active research in materials science. Speakers include researchers at universities, government laboratories, and industry. Course is offered both of 1 credit and 0 credits. Attendance is required for both, and graded coursework in the form of a term paper is required when registering for 1 credit. Offered as EMSE 499 and EMSE 599.

EMSE 500T. Graduate Teaching II. 0 Unit.
To provide teaching experience for all Ph.D.-bound graduate students. This will include preparing exams/quizzes/homework, leading recitation sessions, tutoring, providing laboratory assistance, and developing teaching aids that include both web-based and classroom materials. Graduate students will meet with supervising faculty member throughout the semester. Grading is pass/fail. Students must receive three passing grades and up to two assignments may be taken concurrently. Recommended preparation: Ph.D. student in Materials Science and Engineering.

EMSE 503. Structure of Materials. 3 Units.
The structure of materials and physical properties are explored in terms of atomic bonding and the resulting crystallography. The course will cover basic crystal chemistry, basic crystallography (crystal symmetries, point groups, translation symmetries, space lattices, and crystal classes), basic characterization techniques and basic physical properties related to a materials structure.

EMSE 504. Thermodynamics of Solids. 3 Units.

EMSE 505. Phase Transformations, Kinetics, and Microstructure. 3 Units.
Phase diagrams are used in materials science and engineering to understand the interrelationships of composition, microstructure, and processing conditions. The microstructure and phases constitution of metallic and nonmetallic systems alike are determined by the thermodynamic driving forces and reaction pathways. In this course, solution thermodynamics, the energetics of surfaces and interfaces, and both diffusional and diffusionless phase transformations are reviewed. The development of the laws of diffusion and its application for both melts and solids are covered. Phase equilibria and microstructure in multicomponent systems will also be discussed.

EMSE 509. Conventional Transmission Electron Microscopy. 3 Units.
Introduction to transmission electron microscopy-theoretical background and practical work. Lectures and laboratory experiments cover the technical construction and operation of transmission electron microscopes, specimen preparation, electron diffraction by crystals, electron diffraction techniques of TEM, conventional TEM imaging, and scanning TEM. Examples from various fields of materials research illustrate the application and significance of these techniques. Recommended preparation: Consent of instructor.

EMSE 512. Advanced Techniques of Transmission Electron Microscopy. 3 Units.
Theory and laboratory experiments to learn advanced techniques of transmission electron microscopy, including high-resolution transmission electron microscopy (HRETEM), convergent-beam electron diffraction (CBEED), microanalysis using X-ray energy-dispersive spectroscopy (XEDS) and electron energy-loss spectroscopy (EELS), and electron-spectroscopic imaging (ESI) for elemental mapping. Recommended preparation: EMSE 509.

EMSE 515. Analytical Methods in Materials Science. 3 Units.
Microcharacterization techniques of materials science and engineering: SPM (scanning probe microscopy), SEM (scanning electron microscopy), FIB (focused ion beam) techniques, SIMS (secondary ion mass spectrometry), EPMA (electron probe microanalysis), XPS (X-ray photoelectron spectrometry), and AES (Auger electron spectrometry), ESCA (electron spectrometry for chemical analysis). The course includes theory, application examples, and laboratory demonstrations.

EMSE 599. Materials Science and Engineering Colloquium. 0 - 1 Units.
Invited speakers deliver lectures on topics of active research in materials science. Speakers include researchers at universities, government laboratories, and industry. Course is offered both of 1 credit and 0 credits. Attendance is required for both, and graded coursework in the form of a term paper is required when registering for 1 credit. Offered as EMSE 499 and EMSE 599.
EMSE 600T. Graduate Teaching III. 0 Unit.
To provide teaching experience for all Ph.D.-bound graduate students. 
This will include preparing exam/quizzes/homework, leading recitation 
sessions, tutoring, providing laboratory assistance, and developing 
teaching aids that include both web-based and classroom materials. 
Graduate students will meet with supervising faculty member throughout 
the semester. Grading is pass/fail. Students must receive three 
passing grades and up to two assignments may be taken concurrently. 
Recommended preparation: Ph.D. student in Materials Science and 
Engineering.

EMSE 601. Independent Study. 1 - 18 Units.

EMSE 649. Special Projects. 1 - 18 Units.

EMSE 651. Thesis M.S.. 1 - 18 Units.
Required for Master's degree. A research problem in metallurgy, ceramics, 
electronic materials, biomaterials or archeological and art historical 
materials, culminating in the writing of a thesis.

EMSE 695. Project M.S.. 1 - 9 Units.
Research course taken by Plan B M.S. students. Prereq: Enrolled in the 
EMSE Plan B MS Program.

EMSE 701. Dissertation Ph.D.. 1 - 9 Units.
Required for Ph.D. degree. A research problem in metallurgy, ceramics, 
electronic materials, biomaterials or archeological and art historical 
materials, culminating in the writing of a thesis. Prereq: Predoctoral 
research consent or advanced to Ph.D. candidacy milestone.