Department of Materials Science and Engineering Courses

Note on Course Numbers
Each Carnegie Mellon course number begins with a two-digit prefix which designates the department offering the course (76-xxx courses are offered by the Department of English, etc.). Although each department maintains its own course numbering practices, typically the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. xx-6xx courses may be either undergraduate senior-level or graduate-level, depending on the department. xx-7xx courses and higher are graduate-level. Please consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) each semester for course offerings and for any necessary pre-requisites or co-requisites.

27-052 Introduction to NanoScience and Technology
This course is offered within Carnegie Mellon's Advanced Placement Early Admissions (APEA) program. The course is primarily intended to provide an introduction to nanoscience and technology to a wide audience of students at the advanced high school to incoming freshmen level. The course goals are twofold: (1) to provide students with a holistic view of the objectives, opportunities and challenges of the emerging field of nanotechnology and (2) to sensitize students at an early stage of their career to the relevance of the connections among the traditional disciplines as a vital element to the progress in interdisciplinary areas such as nanotechnology. The course will cover: Introduction and fundamental science; Preparation of nanostructures; Characterization of nanostructures; Application examples, Social and ethical aspects of nanotechnology. Admission according to APEA guidelines.

27-100 Engineering the Materials of the Future
Fall and Spring: 12 units
Materials form the foundation for all engineering applications. Advances in materials and their processing are driving all technologies, including the broad areas of nano-, bio-, energy, and electronic (information) technology. Performance requirements for future applications require that engineers continue to design both new structures and new processing methods in order to engineer materials having improved properties. Applications such as optical communication, tissue and bone replacement, fuel cells, and information storage, to name a few, exemplify areas where new materials are required to realize many of the envisioned future technologies. This course provides an introduction to how science and engineering can be exploited to design materials for many applications. The principles behind the design and exploitation of metals, ceramics, polymers, and composites are presented using examples from everyday life, as well as from existing, new, and future technologies. A series of laboratory experiments are used as a hands-on approach to illustrating modern practices used in the processing and characterization of materials and for understanding and improving materials' properties.
Corequisites: 21-120 and 33-106.

27-202 Defects in Materials
Fall: 9 units
Defects have a fundamental influence on the properties of materials, including deformation, electrical, magnetic, optical, and chemical properties, as well as the rates of diffusion in solids. As such, by controlling the population of intrinsic and extrinsic defects, one can tailor the properties of materials towards specific engineering applications. The objective of this course, which includes classroom and laboratory sessions, is to define approaches to quantifying the populations and properties of defects in crystals. The course will be divided into three sections: point defects, dislocations, and planar defects. The formation of point defects and their influence on diffusion, electrical, and magnetic properties will be considered. The properties and characteristics of dislocations and dislocation reactions will be presented, with a focus on the role of dislocations in deformation. The crystallography and energetics of planar defects and interfaces will also be described, with a focus on microstructural evolution at high temperatures. Time permitting, volume defects or other special topics are also discussed.
Prerequisite: 21-122
Corequisite: 27-100.

27-205 Introduction to Materials Characterization
Spring: 3 units
This course introduces the modern methods of materials characterization, including characterization of microstructure and microchemistry of materials. A classroom component of the course will introduce the wide array of methods and applications of characterization techniques. Basic theory will be introduced where needed. Students will then be instructed in the use of several instruments such as AFM, SEM, and EDS, using a hands-on approach. All instruments are part of the existing lab facilities within MSE and CIT. The methods learned in this course will serve the student during several other higher level courses, such as the Senior level MSE Capstone Course (27-401).

27-211 Structure of Materials (Minor Option)
6 units
This course is identical to 27-201, but without the 3-unit lab component.

27-212 Defects in Materials (Minor Option)
6 units
THIS IS FOR THE MSE MINOR ONLY: Defects have a fundamental influence on the properties of materials, including deformation, electrical, magnetic, optical, and chemical properties, as well as the rates of diffusion in solids. As such, by controlling the population of intrinsic and extrinsic defects, one can tailor the properties of materials towards specific engineering applications. The objective of this course, which includes classroom and laboratory sessions, is to define approaches to quantifying the populations and properties of defects in crystals. The course will be divided into three sections: point defects, dislocations, and planar defects. The formation of point defects and their influence on diffusion, electrical, and magnetic properties will be considered. The properties and characteristics of dislocations and dislocation reactions will be presented, with a focus on the role of dislocations in deformation. The crystallography and energetics of planar defects and interfaces will also be described, with a focus on microstructural evolution at high temperatures. Time permitting, volume defects or other special topics are also discussed.

27-215 Thermodynamics of Materials
Fall: 12 units
The first half of the course will focus on the laws of thermodynamics and the inter-relationships between heat, work and energy. The concept of an equilibrium state of a system will be introduced and conditions which must be satisfied for a system to be at equilibrium will be established and discussed and the concepts of activity and chemical potential introduced.
The second half of the course will focus on chemical reactions, liquid and solid solutions, and relationships between the thermodynamics of solutions and binary phase diagrams.
Corequisites: 21-259 and 27-100.
27-216 Transport in Materials  
Spring: 9 units  
This course is designed to allow the student to become familiar with the fundamental principles of heat flow, fluid flow, mass transport and reaction kinetics. In addition, the student will develop the skills and methodologies necessary to apply these principles to problems related to materials manufacture and processing. Topics will include thermal conductivity, convection, heat transfer equations, an introduction to fluid phenomena viscosity, etc., Newtons and Stokes Laws, mass momentum balances in fluids, boundary layer theory, diffusion and absolute reaction rate theory. Where appropriate, examples will be taken from problems related to the design of components and the processing of materials.  
Prerequisites: 15-110 and 27-215  
Corequisite: 09-105.

27-217 Phase Relations and Diagrams  
Spring: 12 units  
Prerequisites: 27-201 and 27-202 and 27-215  
Corequisite: 09-105.

27-299 Professional Development I  
Fall: 3 units  
This is a course that is designed to teach engineering business and professional skills to the MSE students. It is attended by sophomores, juniors and seniors and the courses Professional Topics I, II and III are given once per year on a three year cycle. Year 1: Work Place Skills, Leadership Skills and Teams Year 2: Project Management Year 3: Ethics, Business Planning, Lifetime Learning Although the course is not specifically designed as “metals, polymers, ceramics and composites”, real world problems are used for examples and discussions. Assignments, when used, (for example, in project management or business planning) can be case studies or typical assignments a materials scientist may encounter during his/her employment.

27-301 Microstructure and Properties I  
Fall: 9 units  
The objective of this course and its companion 27-302 is to convey some of the essential concepts in materials science and engineering that relate material properties (strength, magnetism, thermal expansion) to microstructure (crystal structure, dislocations structure, grain structure, precipitate structure, composite structure) in single phase materials. The relationships will be illustrated with examples of both idealized and technological materials. The course will draw upon many aspects of materials science such as defects, phase transformations etc. The course includes both lectures and laboratory exercises.  
Prerequisites: 27-216 and 27-217.

27-302 Microstructure and Properties II  
Spring: 9 units  
The course applies the principles and ideas developed in 27-301 to multiphase materials. The structure-property relationships will be illustrated with examples of both idealized and technological materials. The course will draw upon many aspects of materials science such as defects, phase transformations etc. The course includes both lectures and laboratory exercises.  
Corequisite: 27-301.

27-311 Polymeric Biomaterials  
Spring: 9 units  
This course will provide students with an introduction to polymers used in medical applications. Following a brief discussion of the physical properties of polymers and tissues, we will survey important classes of polymeric biomaterials, discussing material preparation, processing, properties and applications. Topics will include silicone elastomers, degradable hydrogels, ultra-high molecular weight polyethylene, polyurethanes, polyesters, and biopolymers such as silks and collagen. In addition, students will participate in a semester-long entrepreneurship project where they propose a new medical technology based on polymeric biomaterials. This semester we will discuss this primarily in the context of materials for wound healing applications. Student teams will perform market research on wound healing products, propose a novel bioactive dressing for wound healing applications, and identify methods for the testing and production of their product.

27-312 Metallic and Ceramic Biomaterials  
Fall: 9 units  
The course addresses basic and applied concepts of metals and ceramics as biomaterials. The students will be exposed to the principles, properties and applications of amorphous and crystalline inorganic and metallic systems for biological applications. Specific emphasis will be placed on processing biochemical activity, biodegradation mechanisms, and various properties relevant for biological response. Cellular interactions with various surfaces and immunological responses will also be covered. Applications of biomaterials to be discussed include tissue engineering, artificial implants and devices. Part I of this course is offered in the Spring and focuses on the principles, properties and applications of polymers as biomaterials.  
Prerequisites: None, but 09-105 Introduction to Modern Chemistry and 42-101 Introduction to Biomedical Engineering will be useful.

27-322 Processing of Metals  
Fall: 9 units  
This course addresses the principles of processing of metals and the relationship between processing and performance. Topics include chemical thermodynamics, reaction kinetics, surfaces, fundamentals of heat treatment, process engineering, powder handling, powder compaction, densification and sintering. These aspects of processing science will be applied to the processing of metals including electrometallurgy, hydromet- lurgy, pyrometallurgy, extraction, refining, and specific examples of alloy systems such as the production of steel, aluminum or titanium. The principles and practice of materials processing will be applied to process optimization. The relationship between processing methods and the environment will be discussed. The impact of the processing history of materials will be discussed in relation to material performance and lifetime. The concept of the lifecycle of materials will be discussed.

27-333 Powder Processing of Materials  
Fall: 9 units  
This course addresses the methods used in, and the principles that underlie, powder processing of metals and ceramics. Aspects of powder processing will be discussed in relation to the use of materials in engineering applications. The relationship between processing methods and materials performance in select applications will be discussed using specific materials examples including metals and ceramics. The course is broken down into three main parts: (1) understanding, selecting, and controlling powder characteristics; (2) powder handling, compaction, and forming techniques; and (3) drying, burnout, densification, sintering, and grain growth in powder compacts. Topics include chemical thermodynamics, reaction kinetics, surfaces, colloids, dispersions, process engineering, powder handling, powder compaction, shape forming, densification, and sintering.  
Prerequisites: 27-100 and 27-202 and 27-215 and 27-216.

27-324 Introduction to Polymer Science and Engineering  
Fall: 9 units  
This course introduces the fundamental properties of polymer materials and the principles underlying the design as well as the engineering and manufacturing of polymer materials. The basic characteristics of macromolecules will be discussed followed by an introduction to relevant forming technologies and their significance to material performance. Technologically relevant engineering properties of polymer materials will be introduced with focus on mechanical, electrical, and optical properties. Selected case studies and design projects will introduce students to the various stages of technical product development, i.e. problem analysis, material selection and processing plan.

27-325 Polymer Physics and Morphology  
Fall: 9 units  
This course introduces the fundamental concepts necessary to understand the structure of polymers in the solid state. The structure of polymers will be discussed with focus on the amorphous, crystalline and liquid-crystalline state. One aim is to provide the student intuition about the organization of polymer molecules in the solid state based on the polymer’s chemical structure. Attention will be given to the phenomenon of glass transition in amorphous polymers as well as the morphology and kinetics of crystal formation in semi-crystalline polymers. The second part of the course will focus on polymer multicomponent materials. Basic concepts of lattice models will be introduced and applied to predict the phase behavior of polymer blends. A last section will focus on microdomain formation in block copolymer materials.
27-357 Introduction to Materials Selection
Spring: 6 units
The objective of this course is to teach the fundamentals of materials science as related to metals and metal alloys. The topics to be covered include crystal structure, defects, diffusion, binary phase diagrams, microstructure and processing, elastic and plastic deformation, equations of elasticity for isotropic materials, deformation of single crystal, slip systems, the tensile test, Von Mises yield criteria, strengthening mechanisms, phase transformations in steels, microstructures of steels, fracture and toughness, creep and corrosion.

27-367 Selection and Performance of Materials
Spring: 6 units
This course teaches the selection methodologies for materials and processes for satisfaction of a design goal. Topics such as performance under load, shape effects, material properties (intrinsic and as influenced by processing) are discussed and applied so as to determine the fitness of use of materials for applications. Expanded topics include economics, codes and standards, environmental and safety regulations, professional ethics and life cycle analysis wherever applicable. The course incorporates a project where virtual teams work to provide material selection for a specific application problem. Prerequisites: 27-100
Prerequisites: 27-100 and 27-301.

27-399 Professional Development II
Fall: 1 unit
This is a course that is designed to teach engineering business and professional skills to the MSE students. It is attended by sophomores, juniors and seniors and the courses Professional Topics I, II and III are given once per year on a three year cycle. Year 1: Work Place Skills, Leadership Skills and Teams Year 2: Project Management Year 3: Ethics, Business Planning, Lifetime Learning Although the course is not specifically designed as "metals, polymers, ceramics and composites", real world problems are used for examples and discussions. Assignments, when used, (for example, in project management or business planning) can be case studies or typical assignments a materials scientist may encounter during his/her employment.

27-401 MSE Capstone Course I
Fall: 12 units
This capstone course introduces the student to the methodology used for projects and team based research as practiced in the Materials Science and Engineering workplace. This is a project course that requires the knowledge relationship among processing, structure, and performance to address an important contemporary problem in materials science and engineering. Student taking this course will work in a team environment to complete a design project to resolve scientific and engineering issues relating to materials. Topics will be selected from a list or material problems or research concepts generated from industrial or academia. All research is expected to be original, and proper scientific ethics, and methodologies are enforced for the research and reports. Team participation and communication is an important issue and the presentation and reports must be technical and professional in structure. The course requires full project management and accounting for the research being conducted. On the topic selected, the work product is a report that provides clear definition of the problem being addressed, a methodology for the research, literature review, experimentation and reporting of findings, conclusions based on findings, and recommendations for future work. Prerequisites: 27-205 and 27-367.

27-402 MSE Capstone Course II
Spring: 12 units
This is the spring extension of 27-401. Teams or team members that have the industry agreement and that wish to continue their research project may do so in this course. As with 27-401, all research is expected to be original, and proper scientific ethics, and methodologies are enforced for the research and reports. Team participation and communication is an important issue and the presentation and reports must be technical and professional in structure. The course requires full project management and accounting for the research being conducted. On the topic selected, the work product is a report that provides clear definition of the problem being addressed, a methodology for the research, literature review, experimentation and reporting of findings, conclusions based on findings, and recommendations for future work. Prerequisites: 27-401
Prerequisite: 27-401.

27-405 Analysis and Prevention of Product Failures
Intermittent: 9 units
This course focuses on detailed case studies of failures such as recent structural collapses, heart valve fractures, and the sinking of the Titanic. A central focus of all analyses is the determination of the principal cause or causes of failure. These detailed causation determinations will involve techniques ranging from fault tree analysis to fractography by optical and scanning electron microscopy to stress analysis using finite element analysis. The current and potential future role of failure analysis and prevention in regulation and litigation will also be considered in detail, again using technology rich case studies. The final product is an analysis of a specific product failure that is both broadly based and technologically rigorous, combined with a strategy or strategies for its prevention.
Prerequisites: 27-100 or permission of instructor.

27-410 Computational Techniques in Engineering
Spring: 12 units
This course develops the methods to formulate basic engineering problems in a way that makes them amenable to computational/numerical analysis. The course will consist of three main modules: basic programming skills, discretization of ordinary and partial differential equations, and numerical methods. These modules are followed by two modules taken from a larger list: Monte Carlo-based methods, molecular dynamics methods, image analysis methods, and so on. Students will learn how to work with numerical libraries and how to compile and execute scientific code written in Fortran-90 and C++.
Students will be required to work on a course project in which aspects from at least two course modules must be integrated.

27-411 Engineering Biomaterials
Fall: 9 units
This course will cover structure-processing-property relationships in biomaterials for use in medicine. This course will focus on a variety of materials including natural biopolymers, synthetic polymers, and soft materials with additional treatment of metals and ceramics. Topics include considerations in molecular design of biomaterials, understanding cellular aspects of tissue-biomaterials interactions, and the application of bulk and surface properties in the design of medical devices. This course will discuss practical applications of these materials in drug delivery, tissue engineering, biosensors, and other biomedical technologies. Cross-listed with 27-411.

27-421 Processing Design
Fall: 6 units
In this course, the concepts of materials and process design are developed, integrating the relevant fundamental phenomena in a case study of a process design. The course includes basic science and engineering as well as economic and environmental considerations. The case study is on environmentally acceptable sustainable steelmaking. Other case studies in materials processing could be used.

27-432 Electronic and Thermal Properties of Metals, Semiconductors and Related Devices
Intermittent: 9 units
Fall even years This is Part I of a two-part course (Part II is 27-433) sequence concerned with the electrical, dielectric, magnetic and superconducting properties of materials. Students taking Part I will develop an in-depth understanding, based on the modern theories of solids, of the electrical, electronic and thermal properties of metals and semiconductors and the principles of operation of selected products and devices made from these materials. Overarching and interrelated topics will include elementary quantum and statistical mechanics, relationships between chemical bonds and energy bands in metals and semiconductors, the roles of phonons and electrons in the thermal conductivity of solids, diffusion and drift of electrons and holes, the important role of junctions in the establishment and control of electronic properties of selected metal- and semiconductor-based devices. Examples of commercial products will be introduced to demonstrate the application of the information presented in the text and reference books and class presentations. Additional topics will include microelectro-mechanical systems and nanoelectronics.
27-433 Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices
Intermittent: 9 units
Fall odd years: 9 units This is Part II of a two-part course sequence (Part I is 27-432) concerned with the electrical, dielectric, magnetic and superconducting properties of materials. Students taking Part II will develop an in-depth understanding, based on the modern theories of solids, of the dielectric, magnetic and superconducting properties of materials and the principles of operation of selected products and devices made from these materials. Topics will include relationships between chemical bonds and energy bands in dielectric and magnetic materials; polarization mechanisms in materials and their relationship to capacitance, piezoelectricity, ferroelectricity, and pyroelectricity; magnetization and its classification among materials; magnetic domains; soft and hard magnets; and the origin, theory and application of superconductivity. Examples of commercial products will be introduced to demonstrate the application of the information presented in the text and reference books and class presentations.

27-442 Deformation Processing
Intermittent: 9 units
A continuum analysis of plastic flow of isotropic and anisotropic (textured) materials will be applied to deformation processing. Crystallographic models of yielding and plastic flow will also be developed and used to characterize various industrial deformation processing techniques. Prerequisite: 27-441.

27-445 Structure, Properties and Performance Relationships in Magnetic Materials
Spring: 9 units
This course introduces the student to intrinsic properties of magnetic materials including magnetic dipole moments, magnetization, exchange coupling, magnetic anisotropy and magnetostriiction. This is followed by discussion of extrinsic properties including magnetic hysteresis, frequency dependent magnetic response and magnetic losses. This will serve as the basis for discussing phase relations and structure/properties relationships in various transition metal magnetic materials classes including iron, cobalt and nickel elemental magnets, iron-silicon, iron-nickel, iron-cobalt and iron platinum. This will be followed by a discussion of rare earth permanent magnets used in Electromagnetic Interference (EMI) Absorbers applications will also be covered.

27-454 Supervised Reading
Spring
This course provides the opportunity for a detailed study of the literature on some subject under the guidance of a faculty member, usually but not necessarily in preparation for the Capstone Course, 27-401/402.

27-499 Professional Development III
Fall: 1 unit
This is a course that is designed to teach engineering business and professional skills to the MSE students. It is attended by sophomores, juniors and seniors and the courses Professional Topics I, II and III are given once per year on a three year cycle. Year 1: Work Place Skills, Leadership Skills and Teams Year 2: Project Management Year 3: Ethics, Business Planning, Lifetime Learning Although the course is not specifically designed as “metals, polymers, ceramics and composites”, real world problems are used for examples and discussions. Assignments, when used, (for example, in project management or business planning) can be case studies or typical assignments a materials scientist may encounter during his/her employment.

27-501 Invention & Innovation for Materials Intensive Technologies Part 1
Fall: 4.5 units
Two 4.5 unit classes that can be taken in sequence or as stand-alone mini's. Courses will be cross-listed between EPP and MSE. This course is intended to instill a sense of how technologies are conceived and brought to market. The students will be exposed to a variety of formalized invention and innovation processes/concepts and will be asked to complete projects that will pull from the full range of their engineering training. It is intended for seniors who are eager to creatively apply their learned knowledge skills, and who are interested in invention, innovation, and entrepreneurship. The first half (part 1 (27-501), mini 1) will focus on the process of invention for devices and technologies that are enabled by materials functionality. This will start by providing historical context and addressing the questions “What is invention?” This will be followed by an assessment of various systematic methods by which the process of invention is practiced, with a specific focus on materials intensive devices and products. The second half of the course (part 2 (27-502) mini 2) will examine innovation theory in the context of materials intensive technologies. Specifically, the concepts of incumbency, disruption, value chain, supply chain, funding models and paths to market will be addressed. In this class, significant time will be dedicated to covering the impact of international market and technology development.

27-510 Polymeric Biomaterials
Spring: 9 units
This is Part I of a two-part course sequence in Biomaterials. This introductory course will address basic and applied concepts of polymers as biomaterials. The students will be exposed to both fundamental synthetic mechanisms of polymers and their physical and chemical properties. Specific emphasis will be placed on biodegradation mechanisms, mechanical properties, and surface chemistry of polymeric materials. Cellular interactions with various surfaces and immunological responses will be covered. Applications of biomaterials to be discussed include tissue engineering and artificial organs. Part II of this course will be offered in the fall and the focus will be on the principles, properties and applications of ceramics and metals as biomaterials.

27-511 Introduction to Molecular Biomaterials
Intermittent: 12 units
This course will cover structure-processing-property relationships in biomaterials for use in medicine. The vast majority of this course will focus on natural biopolymers, synthetic polymers, and soft materials with additional minor treatment of metals and ceramics. Topics include basic chemical principles, macromolecular design, processing, characterization, and biodegradation mechanisms associated with synthetic polymeric materials. Applications of these materials in drug delivery and tissue engineering will also be discussed. Knowledge gained during the course will be applied in a team-based project in which students must design a novel synthetic polymer to address a specific clinical need.

27-512 Diffraction Methods in Materials Science
Intermittent: 9 units
This is a specialized course in x-ray diffraction intended for advanced undergraduate students or graduate students. The theory and experimental techniques of diffraction in crystalline solids are introduced. Attention is given to the physical concepts behind crystal structure and diffraction, including the direct and reciprocal lattices, Bragg and Laue diffraction theories and structure-factor calculations. The experimental methods of x-ray and electron diffraction are presented, with emphasis on x-ray diffraction. Topics include the production and scattering of x-rays, factors affecting the scattered intensity, and techniques for obtaining and interpreting diffraction patterns. Pre-requisites: 33-107 (or equivalent), 27-201 or 27-211
Prerequisites: 27-201 and 33-107.

27-520 Tissue Engineering
Spring: 12 units
This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurements of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Prereqs: Cell biology and Biomaterials, or permission of instructor.
27-530 Advanced Physical Metallurgy
Fall: 9 units
The purpose of this course is to develop a fundamental understanding of the evolution of microstructure in engineering alloys and how desired mechanical and physical properties can be obtained by control of microstructure. The first part of the course considers phase stability, phase diagrams and the thermodynamics, mechanisms and kinetics of phase transformations. The second part of the course concerns property microstructure relationships in engineering alloys and how the concepts covered in the first part of the course can be used to obtain the desired microstructures.

27-533 Principles of Growth and Processing of Semiconductors
Fall: 6 units
Development of a fundamental understanding of material principles governing the growth and processing of semiconductors. Techniques to grow and characterize bulk crystals and epitaxial layers are considered. The processing of semiconductors into devices and the defects introduced thereby are discussed. The roles of growth- and processing-induced defects in determining long term reliability of devices are examined.

27-542 Processing and Properties of Thin Films
Fall: 9 units
This course is designed to provide an introduction to the science and technology of thin films, with special emphasis on methods to produce thin films and relationships between growth conditions and thin film properties. Topics include (1) various methods of thin film production, such as evaporation, sputtering and chemical vapor deposition, (2) nucleation and growth processes, (3) dimensional, chemical, and structural characterization of thin films and (4) properties and applications, such as conductivity and thin film solar cells.

27-551 Properties of Ceramics and Glasses
Spring: 9 units
This course describes some of diverse properties of ceramics and glasses, with a focus on those relevant to modern engineering applications. It includes discussions of the underlying science of selected ceramic properties, such as thermal properties, including heat capacity and thermal expansion; mechanical properties, including strength, toughness, and environmental effects; electrical properties, including electronic and ionic conductivity; dielectric properties, including piezoelectricity and ferroelectricity; and optical properties, as they pertain to glasses and lasers. Numerous examples of current applications, such as lasers, sensors, fiber optics, multilayer capacitors, solid oxide fuel cells, or thermoelectrics, are discussed throughout the course to illustrate the engineering relevance of fundamental phenomena. This class will be co-taught with 27-751. Undergraduates taking the course will have separate homework and exams from the graduate students, and will be graded separately from the graduate students.

27-555 Materials Project I
Fall
This course is designed to give experience in individualized research under the guidance of a faculty member. The topic is selected by mutual agreement, and will give the student a chance to study the literature, design experiments, interpret the results and present the conclusions orally and in writing.

27-556 Materials Project II
Spring
Second semester of Materials Project. This course is designed to give experience in individualized research under the guidance of a faculty member. The topic is selected by mutual agreement, and will give the results and present the conclusions orally and in writing.

27-561 Special Topics: Kinetics of Metallurgical Reactions and Processes
6 units

27-565 Nanostructured Materials
Intermittent: 9 units
Fall even years: This course is an introduction to nanostructured materials or nanomaterials. Nanomaterials are objects with sizes larger than the atomic or molecular length scales but smaller than microstructures with at least one dimension in the range of 1-100 nm. The physical and chemical properties of these materials are often distinctively different from bulk materials. This course introduces the basic thermodynamic concepts related to the phases, chemical activity and synthesis of nanomaterials including metallic, semiconductor, inorganic, liquid crystalline, polymeric and surfactant systems. The characterization of the structure of nanomaterials and their applications are also explored. At the end of the course, students should understand the relationship between the nanoscale structures, properties and performance of nanomaterials.

27-566 Special Topics in MSE: Using Matlab Informatics to Assess Societal Impact of Mats
Fall and Spring: 9 units
Using Materials Informatics to Assess Societal Impact of Materials: For years Material Science and Engineering in general has been taught with emphasis on the technology and then looks at how this technology fits in to society through applications. This course will attempt to put forth an innovative approach, combining new data mining techniques, data analysis, and material fundamentals (materials informatics) to see if material failure patterns can be extracted from social media. The course will involve instruction on typical material issue that contribute to failures either geographically or temporarily. Students will also be introduced to informatics techniques related to data mining and large database analysis. The intent is to have a mix of lectures and practical project work. This course is primarily intended to be a course directed to CIT students in order to experience an understanding that engineering work is strongly connected to societal. Students that enroll should have completed their class in statistics.

27-570 Molecular and Micro-scale Polymeric Biomaterials in Medicine
9 units
This course will cover aspects of polymeric biomaterials in medicine from molecular principles to device scale design and fabrication. Topics include the chemistry, characterization, and processing of synthetic polymeric materials; cell-biomaterials interactions including interfacial phenomena, tissue responses, and biodegradation mechanisms; aspects of polymeric micro-systems design and fabrication for applications in medical devices. Recent advances in these topics will also be discussed. Pre-requisite: None.

27-582 Phase Transformations in Solids
Intermittent: 9 units
Spring even years: In this course the fundamental aspects of solid state phase transformations are presented. The nucleation (homogeneous and heterogeneous) and growth of diffusional and non-diffusional heterogeneous solid state transformations are discussed from the point of view of crystallography, thermodynamics and kinetics, as are the same aspects of homogeneous transformations. Details of such transformations as precipitation, cellular, atomic ordering, massive, spinodal decomposition, displacive, etc. are discussed with specific examples from the Materials Science literature.

27-591 Mechanical Behavior of Materials
Intermittent: 9 units
Spring odd years: Fundamentals of stress and strain. Linear elastic behavior. Tensile testing and yield criteria. Relationships between stress and strain for the case of plastic deformation. Theoretical strength. Tensile tests of single crystals and the idea of a slip system. Shear stress versus shear strain curves for single crystals and the effects of crystal orientation, temperature, atoms in solid solution and precipitates on the shapes of such curves. Taylor's connection between tensile curves of single crystals and those of polycrystalline samples. Dislocations and plastic deformation. Strengthening mechanisms including solid-solution strengthening, strengthening by precipitates, work hardening and grain size effects on strength. Approaches to quantifying the fracture resistance of materials, including the Griffith approach, the energy release rate approach and the stress intensity factor approach. Crack tip behavior including stresses and strains at crack tips and the plastic zone. Fracture mechanisms including ductile fracture, cleavage fracture and intergranular fracture. The fracture of highly brittle materials. Time permitting fatigue and creep of materials will be discussed.
27-592 Solidification Processing
Intermittent: 9 units
Spring odd years: The goal of this course is to enable the student to solve practical solidification processing problems through the application of solidification theory. The objectives of this course are to: (1) Develop solidification theory so that the student can understand solidification structure; (2) Develop a strong understanding of the role of heat transfer in castings; (3) Develop an appreciation for the strengths and weaknesses of a variety of casting processes. The first half of the course will be theoretical, covering nucleation, growth, instability, solidification microstructure: cells, dendrites, eutectic and peritectic structures, solute redistribution, inclusion formation and separation, defects and heat transfer problems. The second part of the course will be process oriented and will include conventional and near net shape casting, investment casting, rapid solidification and spray casting where the emphasis will be on process design to avoid defects.

27-594 Electrochemical Degradation of Materials
Intermittent: 9 units
This course is designed to provide an overview of how metallic material degrade through electrochemical processes in various environments. This will include aqueous corrosion of active and passive alloys and high-temperature oxidation. The fundamentals of electrochemical cells, electrochemical potentials and electrode kinetics will be introduced and used to predict corrosion rates in various case studies. Prerequisite: 27-215.

27-699 Professional Skills in Materials Science and Engineering
Fall: 6 units
This course is intended for students in the masters program in Materials Science and Engineering. The course will expose students to important issues that materials scientists and engineers face when they enter the workforce. The course focuses on professional skills for materials scientists and engineers, covering communication skills, ethics and responsible conduct of research, and evaluating technical literature. The course will end with discussions on how materials science affects the global economy. Course activities will include in-class exercises and assignments based on case studies.

27-709 Engineering Biomaterials
Fall: 6 units
This course will cover structure-processing-property relationships in biomaterials for use in medicine. This course will focus on a variety of materials including natural biopolymers, synthetic polymers, and soft materials with additional treatment of metals and ceramics. Topics include considerations in molecular design of biomaterials, understanding cellular aspects of tissue-biomaterials interactions, and the application of bulk and surface properties in the design of medical devices. This course will discuss practical applications of these materials in drug delivery, tissue engineering, biosensors, and other biomedical technologies. This course is a project-based option for graduate students that is taught concurrently with 42-411.

27-718 Soft Materials
Fall: 12 units
The emphasis in this course will be on the emerging unifying physical principles that explain the macroscopic properties of a wide variety of soft materials, e.g., colloids, liquid crystals, surfactants, polymers, and biological structures. At the end of the course, students should understand the concepts, experimental techniques, and open questions in the field. The course is interdisciplinary, and it is expected that enrollment will cover a wide spectrum of students. Therefore, the essential concepts will be taught as necessary. Prerequisites: Graduate standing or permission of instructor.

27-721 Processing Design
Fall: 6 units
In this course, the concepts of materials and process design are developed, integrating the relevant fundamental phenomena in a case study of a process design. The course includes basic science and engineering as well as economic and environmental considerations. The case study is on environmentally acceptable sustainable steelmaking. Other case studies in materials processing could be used.

27-756 Masters Project
All Semesters
Individual research project, including laboratory, theoretical, library or design work followed by a written or oral report on the work accomplished.

27-766 Diffusion in Materials
Fall: 6 units
This course is designed to allow the student to become familiar with the fundamental principles diffusion in solid materials. The course will include the treatment of diffusion from an atomic scale to micro-structural scales in metals, ceramics, glasses and polymers. In addition, the student will develop skills and methodologies necessary to apply mathematical methods to solve differential equations of relevance to diffusion problems including separation of variables, Laplace transforms ad Green's functions. An introduction will be given to the application of numerical solutions. Where appropriate, examples will be taken from problems related to the design of components and the processing and performance of materials.

27-788 Defects in Materials
Fall: 6 units
This course addresses the fundamental properties of defects in crystalline solids, as well as their effects on properties and behavior of materials. Primary attention is devoted to point and line defects. Somewhat less comprehensive coverage is given to extended defects, including grain boundaries, interphase boundaries and surfaces. 4 hrs. lec.

27-791 Mechanical Behavior of Materials
Spring: 12 units
The intent of the course is to introduce various measures indicative of the performance of materials in applications. Properties often used in selecting materials will be introduced, and connections between these properties and microstructure will be developed. Mechanical properties are emphasized in this course. 4 hrs. lec.

27-796 Structure of Materials
6 units
The skills and ideas necessary to understand the atomic structure of crystalline materials are presented. The objective is for the student to be able to describe crystal structures based on their symmetry (Bravais lattices, point groups and space groups) as well as packing configurations and to understand how diffraction is used to experimentally probe crystal structures.

27-797 Bonding of Materials
6 units
Models for cohesive forces in crystals are reviewed; both quantitative and phenomenological descriptions of secondary, ionic, metallic, and covalent bonds are discussed. A band structure language is developed starting from free electron and LCAO models of metals and covalently bonded crystals, respectively. 4 hrs lecture
Prerequisites: 33-225 or 33-234.

27-798 Thermodynamics I
Fall: 6 units
Course Description: The laws, concepts, and definitions of classical thermodynamics as well selected relationships that matter exhibits will be covered and applied to gas, liquid and crystalline systems. Concepts and classifications of thermodynamic systems, variables and relationships will be presented and discussed. General criteria and conditions for equilibrium will be developed and applied. The basic concepts of statistical thermodynamics will be introduced and applied to the interpretation of entropy. Alternate statistical formulations will be introduced and compared.

27-799 Thermodynamics II
Fall: 6 units
Course Description: The course will apply thermodynamic fundamentals covered in Thermodynamics I (27-780) to unary and to multi-component materials systems. The course will also cover phase diagrams, predominance diagrams, chemical reactions and thermodynamics of surfaces.