Applied Physics and Engineering Concentration Planning Guide (based on area of interest)

The Applied Physics and Engineering Track for the B.S. degree for the Physics major requires the following:

- Additional upper- and lower-division requirements (16 units)
  - 16 units of approved Engineering electives including a minimum of 8 units at the upper-division level.

The courses listed below are all approved for the track. Courses not listed may be approved by the Physics Lead Faculty Advisor upon review.

For some classes, important engineering prerequisites are listed so you are aware of them when creating your course plans. Some courses allow "consent of instructor" in place of the course prerequisites. If you do not meet prereqs but the instructor has approved to waive the prereq to enroll, please take a screenshot of their approval and submit the approval to BCOE via an enrollment request form https://bcoe.wufoo.com/forms/bcoe-enrollment-assistance-form/ . **BCOE is the only department that can process these requests as these courses are managed by BCOE.**

You are strongly encouraged to plan a complete 16+-unit sequence of courses for the track before you commit to the track. Make sure that it's possible to complete all of the courses before your planned graduation date. Always check the current catalog as things may have changed since the last update of this list. **BCOE courses may be offered at select times throughout the year. Please consult with BCOE advising if you have questions on the availability of BCOE courses https://student.engr.ucr.edu/**

Approved Applied Physics and Engineering courses

- Computer Science (CS)
- Engineering (ENGR)
- Electrical and Computer Engineering (EE)
- Mechanical Engineering (ME)
- Chemical and Environmental Engineering (CHE)
- Bioengineering (BIEN)
- Materials Science and Engineering (MSE)
- Data Science (DTSC)

Computer Science (CS)

Please note almost all upper-division courses will require you to take CS 010A, CS 010B, and CS 010C, which is a total of 12 units. You will still need to take at least 8 units of upper-division CS courses. If you take CS 009A instead of CS 010A, you may not be able to take any other CS courses, since you cannot earn credit for CS010A after taking CS009A.

CS 010A is a general degree requirement for the major, so these 4 units do not count toward the 16 required units for the Applied Physics and Engineering Track.

Course Number	Units	Course Title	Catalog Description
			LOWER DIVISION
***CS010A**	**4**	**Introduction to Computer Science For Science, Mathematics, and Engineering I**	**Prerequisite(s): MATH 004, may be taken concurrently or MATH 005A, may be taken concurrently or MATH 006A, may be taken concurrently or MATH 006B, may be taken concurrently or MATH 007A, may be taken concurrently or MATH 009A, may be taken concurrently or MATH 09HA. Covers problem solving through structured programming of algorithms on computers using the C++ object-oriented language. Includes variables, expressions, input/output (I/O), branches, loops, functions, parameters, arrays, strings, file I/O, and classes. Also covers software design, testing, and debugging. Credit is awarded for one of the following CS 010A or CS 009A. Credit is not awarded for CS 005 or CS 008 if it has already been awarded for CS 010A.**
CS010B	4	Introduction to Computer Science For Science, Mathematics, and Engineering II	Prerequisite(s): CS 010A with a grade of C- or better; familiarity with C or C++ language. Covers structured and object-oriented programming in C++. Emphasizes good programming principles and development of substantial programs. Topics include recursion, pointers, linked lists, abstract data types, and libraries. Also covers software engineering principles. Credit is awarded for one of the following CS 010B or CS 009B
CS010C	4	C Introduction to Data Structures and Algorithms	Prerequisite(s): CS 010B with a grade of C- or better or CS 009C with a grade of C- or better; proficiency in C++. Topics include basic data structures such as arrays, lists, stacks, and queues. Covers dictionaries (including binary search trees and hashing) and priority queues (heaps). Offers an introductory analysis of algorithms, sorting algorithms, and object-oriented programming including abstract data types, inheritance, and polymorphism. Explores solving complex problems through structured software development.
CS011	4	Introduction to Discrete Structures	Prerequisite(s): CS 010A or MATH 005C or MATH 007B or MATH 009B or MATH 09HB. Introduction to basic concepts of discrete mathematics emphasizing applications to computer science. Topics include propositional and predicate calculi, elementary set theory, functions, relations, proof techniques, elements of number theory, enumeration, and discrete probability. Cross-listed with MATH 011.
CS015	4	Introduction to Data Science	Prerequisite(s): CS 009A with a grade of C- or better. Provides an introduction to data science with an emphasis on empirical analysis of real-world data sets through computation. Explores critical concepts and skills in computer programming and statistical inference. Covers the Data Science life-cycle including data collection, data cleaning and integration, visualization, and analysis.
CS061	4	Machine Organization and sembly Language Programming	Prerequisite(s): CS 010A with a grade of C- or better. An introduction to computer organization. Topics include number representation, combinational and sequential logic, computer instructions, memory organization, addressing modes, interrupt, input/output (I/O), assembly language programming, assemblers, and linkers.
			UPPER DIVISION
CS100	4	Software Construction	Prerequisite(s): CS 010C with a grade of C- or better. Emphasizes development of software systems. Topics include design and implementation strategies and selection and mastery of programming languages, environment tools, and development processes. Develops skill in programming, testing, debugging, performance

			evaluation, component integration, maintenance, and documentation. Covers professional and ethical responsibilities and the need to stay current with technology.
CS105	4	Data Analysis Methods	Prerequisite(s): CS 009B with a grade of C- or better or CS 010B with a grade of C- or better; restricted to class level standing of sophomore, junior, senior, or masters. An introduction to fundamental concepts and methods in data analysis and visualization essential to a variety of data science tasks. Designed to provide preparation for the data science major and for advanced courses in data analysis and applications of data science.
CS111	4	Discrete Structures	Prerequisite(s): CS 010A; CS 011 or MATH 011; MATH 009C or MATH 09HC; MATH 031 or EE 020B. A study of discrete mathematical structures emphasizing applications to computer science. Topics include number theory and cryptography, asymptotic notation, recurrence equations, counting methods, elements of graph theory, and trees.
CS120A	5	Logic Design	Prerequisite(s): CS 061 with a grade of C- or better. Covers design of digital systems. Includes Boolean algebra; combinational and sequential logic design; design and use of arithmetic logic units, carry-lookahead adders, multiplexors, decoders, comparators, multipliers, flip-flops, registers, and simple memories; state-machine design; and basic register-transfer level design. Uses hardware description languages, synthesis tools, programmable logic, and significant hardware prototyping. Cross-listed with EE 120A.
CS120B	4	Introduction to Embedded Systems	Prerequisite(s): CS 010B; CS 120A or EE 120A. Introduction to hardware and software design of digital computing systems embedded in electronic devices (e.g., digital cameras or portable video games). Includes embedded processor programming, custom processor design, standard peripherals, memories, interfacing, and hardware/software tradeoffs. Involves use of synthesis tools, programmable logic, microcontrollers, and developing working embedded systems. Crosslisted with EE 120B.
CS122A	5	Intermediate Embedded and Real-Time Systems	Prerequisite(s): CS 010B; CS 120B or EE 120B. Covers software and hardware design of embedded computing systems. Includes hardware and software codesign, advanced programming paradigms (including state machines and concurrent processes), real-time programming, operating systems, basic control systems, modern chip, and design technologies. Laboratories involve use of microcontrollers, embedded microprocessors, programmable logic, advanced simulation, and debug environments.
CS122B	5	Advanced Embedded and RealTime Systems	Prerequisite(s): CS 122A. Explores state-of-the-art aspects of building embedded computer systems. Topics include real-time programming, synthesis of coprocessor cores, application-specific processors, hardware and software cosimulation and codesign, low-power design, reconfigurable computing, core-based design, and platform-based methodology.
CS130	4	Computer Graphics	Prerequisite(s): CS 100; MATH 031, may be taken concurrently or EE 020B, may be taken concurrently; or consent of instructor. A study of the fundamentals of computer graphics necessary to design and build graphics applications. Examines raster graphics algorithms including scan-converting graphics primitives, anti-aliasing, and clipping. Also covers geometric transformations, viewing, solid modeling techniques, hidden surface removal algorithms, color models, illumination, and shading
CS141	4	Intermediate Data Structures and Algorithms	Prerequisite(s): CS 010C with a grade of C- or better; CS 111; MATH 009C or MATH 09HC; proficiency in C++. Explores basic algorithm analysis using asymptotic notations, summation and recurrence relations, and algorithms and data structures for discrete structures including trees, strings, and graphs. Also covers general algorithm design techniques including “divide-and-conquer,” the greedy method, and dynamic programming. Integrates knowledge of data structures, algorithms, and programming.
CS145	4	Combinatorial Optimization Algorithms	Prerequisite(s): CS 141; MATH 031 or MATH 131. The study of efficient algorithm design techniques for combinatorial optimization problems. Topics include shortest paths, minimum spanning trees, network flows, maximum matchings, stable matchings, linear programming, duality, two-person games, algorithmic techniques for integer programming problems, NP-completeness, and approximation algorithms

CS150	4	Automata and Formal Languages	Prerequisite(s): CS 010C with a grade of C- or better; CS 111; MATH 009C or MATH 09HC. A study of formal languages. Includes regular and context-free languages; computational models for generating these languages such as finite-state automata, pushdown automata, regular expressions, and contextfree grammars; mathematical properties of the languages and models; and equivalence between the models. Also introduces Turing machines and decidability.
CS152	4	Compiler Design	Prerequisite(s): CS 061; CS 100; CS 111; CS 150. Covers the fundamentals of compiler design. Includes lexical analysis, parsing, semantic analysis, compile-time memory organization, run-time memory organization, code generation, and compiler portability issues.
CS153	4	Design of Operating Systems	Prerequisite(s): CS 061; CS 100; CS 111; C++ programming proficiency. Covers the principles and practice of operating system design. Includes concurrency, memory management, file systems, protection, security, command languages, scheduling, and system performance
CS160	4	Concurrent Programming and Parallel Systems	Prerequisite(s): CS 061; CS 100; CS 111. A study of concurrent and parallel systems. Topics include modular structure and design, interprocess communication, synchronization, failures, persistence, and concurrency control. Also covers atomic transactions, recovery, language support, distributed interprocess communication, and implementation mechanisms. Provides preparation for the study of operating systems, databases, and computer networking.
CS161L	4	Design and Architecture of Computer Systems	Prerequisite(s): EE 120A or CS 120A. A study of the fundamentals of computer design. Topics include the performance evaluation of microprocessors; instruction design and measurements of use; microprocessor implementation techniques including multicycle and pipelined implementations; computer arithmetic; memory hierarchy; and input/output (I/O) systems.
CS162	4	Computer Architecture	Prerequisite(s): CS 161 with a grade of “C-” or better. The study of advanced processor design. Topics include CPU pipelining, data and control hazards, instruction-el parallelism, branch prediction, and dynamic scheduling of instructions. Also covers Very Long Instruction Word (VLIW) processing, multimedia support, design of network and embedded processors, basic multiprocessor design, shared memory and message passing, and network topologies.
CS164	4	Computer Networks	Prerequisite(s): CS 100; CS 111; CS 153. Covers the fundamentals of computer networks. Topics include layered network architecture, communication protocols, local area networks, UNIX network programming, verification, network security, and performance studies.
CS165	4	Computer Security	. Prerequisite(s): CS 141, CS 153. Examines the ways in which information systems are vulnerable to security breaches. Topics include attacks; security labels, ttices, and policies; safeguards and countermeasures; intrusion detection; authorization and encryption techniques; networks; digital signatures, certificates, and passwords; privacy issues, firewalls, and spoofing; Trojan horses and computer viruses; CERT Coordination Center; and electronic commerce
CS166	4	Database Management Systems	Prerequisite(s): CS 100; CS 111. Covers basic concepts of databases and database management systems. Topics include entity-relationship modeling for design, onal data model, relational algebra, Structured Query Language (SQL), secondary storage, indexing and hashing, query evaluation and optimization, and overview of transactions.
CS167	4	Introduction to Big-Data Management	Prerequisite(s): CS 100, CS 111; CS 167 online section: enrollment in the online Master-of Science in Engineering program. Introduces the architecture of big-data tems and their applications in data management and processing. Describes the common functionality in big-data processing such as distributed storage, resource nagement, query processing, fault-tolerance, and programming APIs. Covers the popular bigdata technologies such as distributed shared nothing systems, NoSQL processing model, and semi-structured data management.
CS168	4	Introduction to Very Large Scale Integration Design	Prerequisite(s): CS 120A or EE 120A; or consent of instructor. Studies integrated circuit fabrication, device characterization, and circuit simulation. Introduces basic ce physics and physical design rules, MOS logic design, and timing and clock schemes. Covers layout generation, subsystem designs, and circuits for alternative logic s. Also covers design and simulation using hardware description language and CAD tools. Cross-listed with EE 168. Credit is awarded for one of the following EE 168, CS 168, or EE 282A.

CS169	4	Mobile Wireless Networks	Prerequisite(s): CS 153 or consent of instructor. Introduces the fundamentals of wireless and mobile networks. Covers wireless channel models, MAC protocols, ireless network architectures. Also covers cellular, WLAN and ad hoc networks, and routing in multi-hop wireless networks. Includes wireless security and the impact of wireless links on TCP and other transport layer solutions.
CS170	4	Introduction to Artificial Intelligence	Prerequisite(s): CS 100 with a grade of "C-" or better, CS 111. An introduction to the field of artificial intelligence. Focuses on discrete-valued problems. Covers heuristic search, problem representation, and classical planning. Also covers constraint satisfaction and logical inference.
CS171	4	Introduction to Machine Learning and Data Mining	Prerequisite(s): MATH 010A; MATH 031 or EE 020B; STAT 155 or EE 114 or STAT 156A; CS 100 or EE 016. Introduces formalisms and methods in data mining and machine learning. Topics include data representation, supervised learning, and classification. Covers regression and clustering. Also covers rule learning, function approximation, and margin based methods. Cross-listed with EE 142.
CS172	4	Introduction to Information Retrieval	Prerequisite(s): CS 100; CS 111; EE 114 or STAT 155. Introduces information retrieval (IR) principles and techniques for indexing and searching document collections. Topics include Web search, text processing, ranking algorithms, search in social networks, and search evaluation. Also studies scalability issues in search engines. Satisfactory (S) or No Credit (NC) grading is not available.
CS175	4	Entrepreneurship in Computing	Prerequisite(s): CS 100; restricted to class level standing of junior, or senior. Introduces business and technological concepts to create companies based on computer technology. Covers technical aspects of real-world IT projects. Includes developing software and services; understanding user requirements; designating usable systems; and assessing technology. Addresses market analysis and strategy; legal and intellectual property; ethics and communication issues; and financial analysis.
CS177	4	Modeling and Simulation	Prerequisite(s): CS 100; CS 111; C++ programming proficiency. Covers validation of random number sequences; concepts in modeling and systems analysis; and conceptual models and their mathematical and computer realizations. Examines simulation modeling techniques including object-oriented modeling and discrete-event modeling. Emphasizes the use of simulation libraries used with programming languages such as C++.
CS179 (E-Z)	4	Project in Computer Science	Prerequisite(s): CS 100 with a grade of C- or better; CS 152 with a grade of C- or better; ENGR 180W. For hours and prerequisites, see segment descriptions. Under the direction of a faculty member, student teams propose, design, build, test, and document software and/or hardware devices or systems. Emphasizes professional and ethical responsibilities and the need to stay current on technology and its global impact on economics, society, and the environment.
CS179E	4	Project in Computer Science: Compilers	Prerequisite(s): CS 100 and CS 152 with grades of "C-" or better; ENGR 180W; 8 additional upper division units in Computer Science. Covers the planning, design, implementation, testing, and documentation of a compiler-related system. Incorporates techniques from previous related courses. Emphasizes professional and ethical responsibilities; the need to stay current on technology; and its global impact on economics, society, and the environment.
CS179F	4	Project in Computer Science: Operating Systems	Prerequisite(s): CS 153 with a grade of "C-" or better; ENGR 180W; 8 additional upper-division units in Computer Science. CS 160 is recommended. Covers the planning, design, implementation, testing, and documentation of an operating systems related system. Incorporates techniques from previous related courses. Emphasizes professional and ethical responsibilities; the need to stay current on technology; and its global impact on economics, society, and the environment.
CS179G	4	Project in Computer Science: Database Systems	Prerequisite(s): CS 100 with a grade of C- or better; CS 166 with a grade of Cor better or CS 167 with a grade of C- or better, ENGR 180W; 8 additional upper-division units in Computer Science. Covers the planning, design, implementation, testing, and documentation of a database-related system. Incorporates techniques from previous related courses. Emphasizes professional and ethical responsibilities; the need to stay current on technology; and its global impact on economics, society, and the environment.
CS179I	4	Project in Computer Science: Networks	Prerequisite(s): CS 100 and CS 164 with grades of "C-" or better; ENGR 180W; 8 additional upper division units in Computer Science. Covers the planning, design, implementation, testing, and documentation of a network-related system. Incorporates techniques from previous related courses. Emphasizes professional and ethical responsibilities; the need to stay current on technology; and its global impact on economics, society, and the environment.

CS179J	4	Project in Computer Science: puter Architecture and Embedded Systems	Prerequisite(s): CS 100, CS 111, CS 120B/EE 120B, and CS 161 with grades of "C-" or better or consent of instructor; ENGR 180W; 3 additional upper-division units in Computer Science. Covers the planning, design, implementation, testing, and documentation of a computer architecture and embedded systems-related system. Incorporates using techniques presented in previous related courses. Emphasizes professional and ethical responsibilities; the need to stay current on technology; and its global impact on economics, society, and the environment.
CS179K	4	Project in Computer Science: Software Engineering	Prerequisite(s): CS 180; ENGR 180W; 8 additional upper-division units in Computer Science. Covers the planning, design, implementation, testing, and documentation of a software engineering-related system. Incorporates techniques presented in previous related courses. Emphasizes professional and ethical responsibilities; the need to stay current on technology; and its global impact on economics, society, and the environment.
CS179M	4	Project in Computer Science: Artificial Intelligence	Prerequisite(s): CS 100, CS 111, and CS 170 with grades of "C-" or better; ENGR 180W; 8 additional upper-division units in Computer Science. Covers the planning, design, implementation, testing, and documentation of an artificial intelligence-related system. Incorporates techniques presented in previous related courses. Emphasizes professional and ethical responsibilities; the need to stay current on technology; and its global impact on economics, society, and the environment.
CS179N	4	Project in Computer Science: Graphics and Electronic Games	Prerequisite(s): CS 130 with a grade of C- or better; ENGR 180W; 8 additional upper division units in Computer Science. Covers the planning, design, implementation, testing, and documentation of a graphics or electronic game-related system. Incorporates using techniques presented in previous related courses. Emphasizes professional and ethical responsibilities; the need to stay current on technology; and its global impact on economics, society, and the environment.
CS180	4	Introduction to Software Engineering	Prerequisite(s): CS 100. A study of software engineering techniques for the development, maintenance, and evolution of large software systems. Topics include requirements and specification; system design and implementation; debugging, testing, and quality assurance; reengineering; project management; software process; tools; and environments.
CS181	4	Principles of Programming Languages	Prerequisite(s): CS 061; CS 100; CS 111; CS 150. Covers the principles of programming language design. Includes the study and comparison of several programming languages, their features, and their implementations.
CS182	4	Software Testing and Verification	Prerequisite(s): CS 100. A study of modern techniques to assess the quality of software artifacts through functional, performance, and reliability testing. Introduces black box and white box testing techniques. Covers the application of modern testing tools to software units, components, subsystems, and entire systems. Also covers verification as a complementary technique to testing.
CS183	4	Unix System Administration	Prerequisite(s): CS 100. Explores the technical aspects of system administration on a Unix system including advanced Unix. Includes managing system devices, operating system installation, communications, and networking.

Engineering (ENGR)

ENGR118	4	Engineering Modeling and Analysis	Prerequisite(s): CHEM 001A or CHEM 01HA; CS 009A; MATH 046; PHYS 040B or PHYS 040HB; or consent of instructor. Covers the formulation of mathematical models for engineering systems. Includes applying mass, momentum, and energy balances to derive governing differential equations; solving equations with the use of spreadsheets and other software packages; and fitting linear and nonlinear models to experimental data. Credit is awarded for one of the following ENGR 118 or ME 118.
ENGR 160	4	Introduction to Engineering Optimization Techniques	Prerequisite(s): MATH 010A; CS 010A or EE 020B or ME 018A, ME 018B; for the ENGR 160 online section; enrollment in the Master-in-Science in Engineering program. Introduction to formulating and solving optimization problems in engineering. Includes single-variable and multi-variable optimization; linear programming - simplex method; nonlinear unconstrained optimization-gradient, steepest descent, and Newton methods; and nonlinear constrained

			optimization - gradient projection methods. Addresses applications of optimization in engineering design problems. Solves various engineering optimization examples using MATLAB. Credit is awarded for one of the following ENGR 160 or EE 284A

Electrical and Computer Engineering (EE)

		Lower Division	
EE020B	4	Linear Methods for Engineering Analysis and Design Using MATLAB	Prerequisite(s): CS 010A; MATH 009A or MATH 09HA. Introduces MATLAB programming and linear methods for engineering analysis and design. Topics include formulating engineering problems as linear systems of equations; methods for finding their solutions; vector and matrix representations of signals and systems; matrices computations; and linear programming for system analysis and design. Credit is awarded for one of the following EE 020B or MATH 031.
		Upper Division	
EE100A	4	Electronic Circuits	Prerequisite(s): EE 030B. Topics include small-signal modeling of electronic circuits; DC biasing of small-signal bipolar and field-effect transistor amplifiers; current mirrors, cascodes, differential amplifiers, and multistage amplifiers; analysis and design of negative feedback circuits; and modeling of electronic circuits with Spice.
EE100B	4	Electronic Circuits II	Prerequisite(s): EE 100A. Covers analysis and design of advanced electronic circuits. Includes active filters; output stages and power amplifiers; comparator and timer circuits; signal and function generators; complementary metal-oxide system logic circuit implementation; signal conditioning circuits; logic interfacing; optoelectronics devices; digital-to-analog and analog-to-digital converters; non-linear circuits; and modeling of electronic circuits with Spice.
EE105	5	Modeling and Simulation of Dynamic Systems	Prerequisite(s): EE 020A or MATH 045; EE 020B or MATH 031; EE 030A. Introduces the mathematical modeling of dynamical systems and their methods of solution. Explores advanced techniques and concepts for analytical modeling and study of various electrical, electronic, and electromechanical systems based upon physical laws. Emphasizes formulation of problems via differential equations. Addresses numerical methods for integration and matrix analysis problems.
EE110A	4	Signals and Systems	Prerequisite(s): EE 020A or MATH 045; EE 020B or MATH 031. Covers basic signals and types of systems, linear time-invariant (LTI) systems, Fourier analysis, uency response, and Laplace transforms for LTI systems. Includes laboratory experiments with signals, transforms, harmonic generation, linear digital filtering, and sampling/aliasing.
EE110B	4	Signals and Systems	Prerequisite(s): EE 110A. Fourier analysis for discrete-time signals and systems, filtering, modulation, sampling and interpolation, z-transforms. Laboratory experiments with signals, transforms, harmonic generation, linear digital filtering, and sampling/aliasing.
EE111	4	Digital and Analog Signals and Systems	Prerequisite(s): EE 020A or MATH 045; EE 020B or MATH 031; or consent of instructor. Covers continuous- and discrete-time signals and systems; linear time-invariant (LTI) systems; impulse response; Fourier analysis; frequency response; Laplace and Z-transforms; and sampling theorem and Nyquist rates. Includes laboratory experiments with signals, transforms, linear digital filtering, and sampling/aliasing
EE114	4	Probability, Random Variables, Random Processes in Electrical Engineering	Prerequisite(s): EE 110A, may be taken concurrently or EE 111, may be taken concurrently. Covers fundamentals of probability theory, random variables, and random processes with applications to electrical and computer engineering. Includes probability theory, random variables, densities, functions of random variables, expectations and moments, and multivariate distributions. Also addresses random processes, autocorrelation function, spectral analysis of random signals, and linear systems with random inputs.

EE115	4	Introduction to Communication Systems	Prerequisite(s): EE 110A or EE 111. Covers spectral density and correlation, modulation theory, amplitude, frequency, phase and analog pulse modulation and demodulation techniques, signal-to-noise ratios, and system performance calculations. Laboratory experiments involve techniques of modulation and demodulation.
EE116	4	Engineering Electromagnetics	Prerequisite(s): EE 030B, may be taken concurrently. Transmission lines, fields and field operators, electrostatic and magnetostatic fields, time-varying fields, electrodynamics, electromagnetic waves, plane waves, guided waves, and applications to engineering problems.
EE117	4	Electromagnetics II	Prerequisite(s): EE 116. Covers applications of Maxwell's equations. Includes skin effect, boundary value problems, plane waves in lossy media, transverse EM waves, hollow metal waveguides, cavity resonators, microstrips, propagation in dielectrics and optical fibers, optical fibers applications, radiation, and antennas. Covers theoretical and computer modeling exercises in basic electromagnetic technology.
EE120A	4	Logic Design	Prerequisite(s): CS 061 with a grade of C- or better. Covers design of digital systems. Includes Boolean algebra; combinational and sequential logic design; design and use of arithmetic logic units, carry-lookahead adders, multiplexors, decoders, comparators, multipliers, flip-flops, registers, and simple memories; state-machine design; and basic register-transfer level design. Uses hardware description languages, synthesis tools, programmable logic, and significant hardware prototyping. Cross-listed with CS 120A.
EE120B	4	Introduction to Embedded Systems	Prerequisite(s): CS 010B; CS 120A or EE 120A. Introduction to hardware and software design of digital computing systems embedded in electronic devices (e.g., digital cameras or portable video games). Includes embedded processor programming, custom processor design, standard peripherals, memories, interfacing, and hardware/software tradeoffs. Involves use of synthesis tools, programmable logic, microcontrollers, and developing working embedded systems. Crosslisted with CS 120B.
EE123	4	Power Electronics	Prerequisite(s): EE 030B; UCR undergraduate majors for summer only; For MSOL EE 123 online sections: enrollment in the Online Master of Science in Engineering. Covers the study of power semiconductor devices. Includes magnetic circuits and components; switch mode converters and power supplies; and single, three-phase, pulse width modulation, and resonant pulse inverters. Addresses voltage controllers; direct current and induction motor drives; and design of motion control drive circuits for robotic and industrial automation systems. Credit is awarded for one of the following EE 123 or EE 286C.
EE128	4	Sensing and Actuation for Embedded Systems	Prerequisite(s): EE 005, may be taken concurrently or EE 030B, may be taken concurrently; EE 120B, may be taken concurrently or CS 120B, may be taken concurrently; or consent of instructor. Covers embedded system design for sensor data acquisition, signal processing, control, and actuation. Explores sensor and motor interface principles (analog-to-digital and digital-toanalog conversion, Nyquist sampling rate, power constraints, and communication with peripherals). Also addresses design principles for instrumentation, embedded software programming, and real-time systems for sensing and control tasks.
EE132	4	Automatic Control	Prerequisite(s): EE 110A or EE 111; or equivalent; or consent of instructor. Covers mathematical modeling of linear systems for time and frequency domain analysis. Topics include transfer function and state variable representations for analyzing stability, controllability, and observability; and closed-loop control design techniques by Bode, Nyquist, and root-locus methods. Laboratories involve both simulation and hardware exercises. Credit is awarded for one of the following EE 132 or ME 121.
EE133	4	Solid-State Electronics	Prerequisite(s): EE 005 or EE 030B. Presents the fundamentals of solid-state electronics. Topics include electronic band structure; Fermi and quasiFermi levels; doping; contacts; junctions; field effect, bipolar, and metal-oxide-semiconductor (MOS) transistors; and charge-coupled devices. Also reviews device fabrication concepts.
EE135	4	Analog Integrated Circuit Layout and Design	Prerequisite(s): EE 100A; or consent of instructor. Covers analog circuit design, layout, and verification of complementary metal oxide semiconductors (CMOSs) with use of computer-aided design tools. Topics covered include analog metal oxide semiconductor field effect transistor (MOSFET) models, current sources,

			references, amplified design, nonlinear analog circuits, dynamic analog circuits, analog-to-digital converters (ADCs), and digital-to-analog converters (DACs). Credit is awarded for one of the following EE 135 or EE 282C.
EE136	4	Semiconductor Device Processing	Prerequisite(s): EE 133; or equivalent. Presents device simulations and hands-on experience in integrated-circuit fabrication techniques and device characterization. Uses four-mask metal-oxide semiconductor (MOS) technology to fabricate resistors, junctions, capacitors, and MOS transistors as well as to perform electrical evaluation. Credit is awarded for one of the following EE 136 or EE 285A.
EE137	4	Introduction to Semiconductor Optoelectronic Devices	Prerequisite(s): EE 133. An introduction to semiconductor optoelectronic devices for optoelectronic communications and signal processing. Topics include basic optical processes in semiconductors, semiconductor light-emitting diode, semiconductor heterojunction lasers, photodetectors, solar cells, optoelectronic modulation, and switching devices. Credit is awarded for one of the following EE 137 or EE 285B.
EE138	4	Electrical Properties of Materials	Prerequisite(s): PHYS 040C or PHYS 04HC; or equivalent; restricted to class level standing of junior, or senior. Introduces the electrical properties of materials. Includes the electron as a particle and a wave; hydrogen atom and the periodic table; chemical bonds; free-electron theory of metals; band theory of solids; semiconductors and dielectrics; measurements of material properties; and growth and preparation of semiconductors. Credit is awarded for one of the following EE 138 or EE 285C.
EE139	4	Magnetic Materials	Prerequisite(s): PHYS 040C or PHYS 040HC; or equivalent; restricted to class level standing of junior, or senior. Introduces fundamentals of magnetic materials for the next-generation magnetic, nanomagnetic, and spintronics-related technologies. Includes basics of magnetism, models of the equivalent magnetic charge and current, paramagnetic and diamagnetic materials, soft and hard magnetic materials, equivalent magnetic circuits, and magnetic system design foundations. Credit is awarded for one of the following EE 139 or EE 285D.
EE141	4	Digital Signal Processing	Prerequisite(s): EE 110B or EE 111. Transform analysis of Linear Time-Invariant (LTI) systems; discrete Fourier Transform (DFT) and its computation; Fourier analysis of signals using the DFT; filter design techniques; and structures for discrete-time systems. Laboratory experiments on DFT, fast Fourier transforms (FFT), infinite impulse response (IIR), finite impulse response (FIR) filter design, and quantization effects.
EE144	4	Introduction to Robotics	Prerequisite(s): EE 020B or MATH 031 or ME 018B; EE 016 or CS 010B or ME 118; EE 106 or CS 141 or ME 120; restricted to class level standing of junior, or senior; or consent of instructor. Provides foundational knowledge on analysis, control, and programming of robots. Considers configuration space; rigid body motion; forward, inverse, and velocity kinematics; dynamics; trajectory planning; robot motion control; localization and mapping; and robot ethics. Integrates hands-on labs to program robots in simulation and experimentally by reading and interpreting sensor data. Crosslisted with ME 144. Credit is awarded for one of the following EE 144, ME 144, or EE 283A.
EE145	4	Robotic Planning and Kinematics	Prerequisite(s): ME 120 or equivalent; or consent on instructor. Motion planning and kinematics topics with an emphasis in geometric reasoning, programming, and matrix computations. Motion planning includes configuration spaces, sensor-based planning, decomposition and sampling methods, and advanced planning algorithms. Kinematics includes reference frames, rotations and displacements, and kinematic motion models. Cross-listed with ME 145.
EE146	4	Computer Vision	*No engineering prerequisites, consent of instructor for PHYS majors*
EE150	4	Digital Communications	Prerequisite(s): EE 114, EE 115. Topics include modulation, probability and random variables, correlation and power spectra, information theory, errors of transmission, equalization and coding methods, shift and phase keying, and a comparison of digital communication systems. Credit is awarded for one of the following EE 150 or EE 281A.
EE151	4	Introduction to Digital Control	Prerequisite(s): EE 132; EE 141. Reviews continuous-time control systems, Z-transform and properties, sampled-data systems, stability analysis and criteria, and frequency domain analysis and design. Addresses transient and steady-state response, state-space techniques, controllability and observability, pole placement,

			observer design, and Lyapunov stability analysis. Laboratory experiments complementary to these topics include simulations and hardware design. Credit is awarded for one of the following EE 151 or EE 283B.
EE152	4	Image Processing	Prerequisite(s): EE 110B or EE 111; or consent of instructor. Covers digital image acquisition, image enhancement and restoration, image compression, and computer implementation and testing of image processing techniques. Provides hands-on experience of complete image processing systems, including image acquisition, processing, and display. Credit is awarded for one of the following EE 152 or EE 281B.
EE153	4	Electric Drives	Prerequisite(s): EE 116; or consent of instructor for graduate students. For EE 153 online section: enrollment in the Online-Master-in-Science in Engineering program. Topics include the study of electromechanical energy conversion, magnetic circuits, and magnetic components. Also explores linear motors, direct-current motors, induction motors, reluctance motors, and synchronous motor drives. Addresses space vectors in alternating current machines and the analysis and design of feedback controllers. Credit is awarded for one of the following EE 153 or EE 286B.
EE162	4	Introduction of Nanoelectronics	Prerequisite(s): EE 133; or consent of instructor; familiarity with MATLAB or equivalent and with basic matrix algebra is recommended. Presents the basic concepts of nanoelectronics focusing on current flow through nanostructured devices. Topics include new paradigms of nanoelectronics, an atomistic view of electrical resistance, Schroedinger's equation, Coulomb blockade, basis functions, band structure, quantum capacitance, level broadening, and coherent transport. Credit is awarded for one of the following EE 162 or EE 285E.
EE165	4	Design for Reliability of Integrated Circuits and Systems	Prerequisite(s): EE 100A; restricted to class level standing of senior; or graduate standing; or consent of instructor. Covers essentials of electrical transient induced failures to integrated circuits (IC) and systems. Addresses basics for different failure and testing models including electrostatic discharge (ESD). Discusses design-for-reliability (DFR) techniques such as ESD protection designs at IC, module, and system levels. Enhances learning with computer aided design (CAD) laboratories. Credit is awarded for one of the following EE 165 or EE 282D.
EE168	4	Introduction to Very Large Scale Integration (VLSI) Design	Prerequisite(s): CS 120A or EE 120A; or consent of instructor. Studies integrated circuit fabrication, device characterization, and circuit simulation. Introduces basic device physics and physical design rules, MOS logic design, and timing and clock schemes. Covers layout generation, subsystem designs, and circuits for alternative logic styles. Also covers design and simulation using hardware description language and CAD tools. Cross-listed with CS 168. Credit is awarded for one of the following EE 168, CS 168, or EE 282A.

Mechanical Engineering (ME)

Please note that Mechanical Engineering has a lot of prereqs, including 14 units of Lower Division courses. You will need to take the minimum 8 units of Upper Division courses. Because of this, it is best to begin taking ME courses early in your academics (2nd year or beginning of your 3rd year).

Lower Division			
ME002	4	Introduction to Mechanical Engineering	Prerequisite(s): PHYS 040A or PHYS 002A or PHYS 02HA or PHYS 040HA or PHYS 041A. An introduction to the field of mechanical engineering. Topics include the mechanical engineering profession; machine components; forces in structures and fluids; materials and stresses; thermal and energy systems; machine motion; and machine design.
ME009	4	Engineering Graphics and Design	Prerequisite(s): none. Covers graphical concepts and projective geometry relating to spatial visualization and communication in design. Includes technical sketching, computer-aided design with solid modeling, geometric dimensioning and tolerancing, and an introduction to the engineering design process.

ME 010	4	Statics	Prerequisite(s): MATH 009C, PHYS 040A or PHYS 040HA. Covers equilibrium of coplanar force systems; analysis of frames and trusses; noncoplanar force systems; friction; and distributed loads.
ME018A	4	Introduction to Engineering Computation	Prerequisite(s): MATH 009A with a grade of C- or better or MATH 09HA with a grade of C- or better; or equivalent. An introduction to the use of MATLAB in engineering computation. Covers scripts and functions, programming, input/ output, and two- and three-dimensional graphing. Introduces data analysis, numerical analysis, and numerical solutions for engineering problems.
ME018B	4	Introduction to Computational Modeling in Mechanical Engineering	Prerequisite(s): ME 018A, PHYS 040A with a grade of C- or better or PHYS 041A with a grade of C- or better. Introduces the concepts of computational modeling in mechanical engineering. Topics include formulation of mathematical models to solve problems involving vector analysis, complex numbers, linear algebra, and differential, and integral calculus. Explores analytical and numerical solutions to problems in mechanical engineering.
Upper Division			
ME100A	4	Thermodynamics	Prerequisite(s): MATH 010A, ME 018B with a grade of C- or better, PHYS 040B or PHYS 040HB. Introduces basic concepts and applications of thermodynamics relevant to mechanical engineering. Topics include work and energy, the first law of thermodynamics, properties of pure substances, system and control volume analysis, the Carnot cycle, heat and refrigeration cycles, the second law of thermodynamics, entropy, and reversible and irreversible processes. Credit is awarded for only one of CHE 100 or ME 100A.
ME100B	4	Thermodynamics	Prerequisite(s): ME 100A. Topics include the second law of thermodynamics, entropy function, entropy production, analysis of cycles, vapor power systems, gas power systems, refrigeration and heat pump systems, equations of state, thermodynamic property relations, ideal gas mixtures and psychometrics, multicomponent systems, combustion, and reacting mixtures.
ME103	4	Dynamics	Prerequisite(s): MATH 046; ME 010 with a grade of C- or better; ME 018B with a grade of C- or better or CS 010B or MATH 031. Topics include vector representation of kinematics and kinetics of particles; Newton's laws of motion; force-mass-acceleration, work energy, and impulse-momentum methods; kinetics of systems of particles and kinematics; and kinetics of rigid bodies.
ME110	4	Mechanics of Materials	Prerequisite(s): ME 010 with a grade of C- or better, MATH 046. Topics include mechanics of deformable bodies subjected to axial, torsional, shear, and bending loads; combined stresses; and their applications to the design of structures. Satisfactory(S) or No Credit(N/C) is not available.
ME113	4	Fluid Mechanics	Prerequisite(s): MATH 046; PHYS 040B or PHYS 040HB; ME 002 with a grade of C- or better; ME 010 with a grade of C- or better; ME 018B with a grade of C- or better. Introduces principles of fluid mechanics relevant to mechanical engineering. Topics include shear stresses and viscosity, fluid statics, pressure, forces on submerged surfaces, Bernoulli and mechanical energy equations, control volume approach, mass conservation, momentum and energy equations, the differential approach, turbulent flow in pipes, and lift and drag. Credit is awarded for one of the following ME 113 or CHE 114.
ME114	4	Introduction to Materials Science and Engineering	Prerequisite(s): CHEM 001B, PHYS 040C or PHYS 040HC; upper-division standing. Covers materials classification, atomic structure and interatomic bonding, crystal structure of metals, imperfections in solids, diffusion, mechanical properties of engineering materials, strengthening mechanisms, basic concepts of fracture and fatigue, phase diagrams, ceramics, polymers, and composites.
ME116A	4	Heat Transfer	Prerequisite(s): MATH 046, ME 113 (ME 113 may be taken concurrently). Introduces the analysis of steady and transient heat conduction, fin and heat generating systems, two-dimensional conduction, internal and external forced convection, natural convection, radiation heat transfer, heat exchangers, and mass transfer. Credit is awarded for only one of CHE 116 or ME 116A.
ME116B	4	Heat Transfer	Prerequisite(s): ME 116A. Covers analytical and numerical methods in heat transfer and fluid mechanics. Topics include heat conduction and convection, gaseous radiation, boiling and condensation, general aspects of phase change, mass transfer principles, multimode heat transfer and the simulation of thermal fields, and the heat transfer process.

ME117	4	Combustion and Energy Systems	Prerequisite(s): ME 100A; ME 113; ME 116A; for ME 117 online section; enrollment in the Online Master of Science in Engineering program; graduate standing. Discusses premixed and diffusion flames; fuel-air thermochemistry; combustion-driven engine design and operation; engine cycle analysis; fluid mechanics in engine components; pollutant formation; and gas turbines.
ME118	4	Mechanical Engineering Modeling and Analysis	Prerequisite(s): MATH 046, ME 018B with a grade of C- or better. Introduces data analysis and modeling used in engineering through the software package MATLAB. Numerical methods include descriptive and inferential statistics, sampling and bootstrapping, fitting linear and nonlinear models to observed data, interpolation, numerical differentiation and integration, and solution of systems of ordinary differential equations. Final project involves the development and evaluation of a model for an engineering system. Credit is awarded for only one of ENGR 118 or ME 118.
ME120	4	Linear Systems and Controls	Prerequisite(s): EE 005 or EE 030A, EE 030LA; CS 010B, MATH 031 or ME 018B. Introduces the modeling and analysis of dynamic systems, emphasizing the common features of mechanical, hydraulic, pneumatic, thermal, electrical, and electromechanical systems. Controls are introduced through state equations, equilibrium, linearization, stability, and time and frequency domain analysis.
ME121	4	Feedback Control	Prerequisite(s): ME 118; ME 120. Introduces the analysis and design of feedback control systems using classical control methods. Topics include control system terminology, block diagrams, analysis and design of control systems in the time and frequency domains, closed-loop stability, root locus, Bode plots, and an introduction to analysis in state-space. Credit is awarded for one of the following ME 121 or EE 132.
ME122	4	Vibrations	Prerequisite(s): ME 103. Covers free and forced vibration of discrete systems with and without damping resonance; matrix methods for multiple degree-offreedom systems; normal modes, coupling, and normal coordinates; and use of energy methods.
ME130	4	Kinematic and Dynamic Analysis of Mechanisms	Prerequisite(s): ME 009, ME 103. Explores the kinematic analysis of planar mechanisms including linkages, cams, and gear trains. Introduces concepts of multibody dynamics.
ME131	4	Design of Mechanisms	Prerequisite(s): ME 130. Involves design of planar, spherical, and spatial mechanisms using both exact and approximate graphical and analytical techniques. Requires a computer-aided design project.
ME133	4	Introduction to Mechatronics	Prerequisite(s): EE 005 or EE 030A, EE 030LA. Introduces hardware, software, sensors, actuators, physical systems models, and control theory in the context of control system implementation. Covers data acquisition (Labview), sensors, actuators, electric circuits and components, semiconductor electronics, logic circuits, signal processing using analog operational amplifiers, programmable logic controllers, and microcontroller programming and interfacing. Uses MATLAB and Simulink.
ME134	4	Microstructural Transformations in Materials	Prerequisite(s): ME 114 or consent of instructor. An introductory study of the fundamentals (thermodynamics and kinetics) controlling microstructural transformations in materials and their application to both liquid-solid and solid-solid transformations. Focuses on the important transformations that ultimately control the microstructures and properties of crystalline solids. Cross-listed with MSE 134.
ME135	4	Transport Phenomena	Prerequisite(s): ME 100A, ME 113, ME 116A. Introduces new concepts of thermodynamics, fluid mechanics, and heat transfer: sychrometry, combustion, one-dimensional compressible flow, and turbomachinery. Integrates the most important concepts of transport of momentum, heat, and mass.
ME136	4	Environmental Impacts of Energy Production and Conversion	Prerequisite(s): ME 100A; ME 113; ME 116A; for the ME 136 online version section; enrollment in the Online Master of Science in Engineering program; graduate standing. Covers thermodynamics, heat transfer, and fluid mechanics as applied to the examination of the environmental impacts of energy production and conversion. Topics include pollution associated with fossil fuel combustion, environmental impacts of energy use, turbulent transport of pollutants, and principles used in the design of pollution control equipment.
ME137	4	Environmental Fluid Mechanics	Prerequisite(s): ME 100A, ME 113. Covers the application of fluid mechanics to flows in the atmosphere and oceans. Topics include hydrostatic balance, Coriolis effects, geostrophic balance, boundary layers, turbulence, tracer and heat transport.

ME138	4	Transport Phenomena in Living Systems	Prerequisite(s): BIEN 105 or ME 113, MATH 046, PHYS 040B or PHYS 040HB. An introduction to the application of the basic conservation laws of mechanics (mass, linear momentum, and energy) to the modeling of complex biological systems. Emphasizes how these concepts can explain and predict life processes.
ME140	4	Ship Theory	Prerequisite(s): ME 103, ME 113. Covers ship hull form, static and dynamic stability, ship response to waves, grounding and flooding, numerical integration of complex three-dimensional curved shapes and mathematical modeling of curved surfaces. Explores engineering approximations necessary for applications of fundamental principles to complex engineering systems such as ships.
ME144	4	Foundations of Robotics	Prerequisite(s): EE 020B or MATH 031 or ME 018B; EE 016 or CS 010B or ME 118; EE 106 or CS 141 or ME 120; restricted to class level standing of junior, or senior; or consent of instructor. Provides foundational knowledge on analysis, control, and programming of robots. Considers configuration space; rigid body motion; forward, inverse, and velocity kinematics; dynamics; trajectory planning; robot motion control; localization and mapping; and robot ethics. Integrates hands-on labs to program robots in simulation and experimentally by reading and interpreting sensor data. Crosslisted with EE 144. Credit is awarded for one of the following EE 144, ME 144, or EE 283A.
ME145	4	Robotic Planning and Kinematics	Prerequisite(s): ME 120 or equivalent; or consent on instructor. Motion planning and kinematics topics with an emphasis in geometric reasoning, programming, and matrix computations. Motion planning includes configuration spaces, sensorbased planning, decomposition and sampling methods, and advanced planning algorithms. Kinematics includes reference frames, rotations and displacements, and kinematic motion models. Cross-listed with EE 145.
ME153	4	Finite Element Methods	Prerequisite(s): ME 118. Covers weak form formulation, the Galerkin method and its computational implementation, mesh generation, data visualization, as well as programming finite element codes for practical engineering applications.
ME156	4	Mechanical Behavior of Materials	Prerequisite(s): senior standing; ME 110; ME 114. Introduces the theory and experimental techniques for testing the mechanical behavior of materials and structures. Covers the fundamental mechanisms of deformation and failure of metals, ceramics, polymers, composite materials, and electronic materials as well as structural design and materials selection.
ME170A	4	Experimental Techniques	Prerequisite(s): EE 005; ME 018B with a grade of C- or better. Covers the principles and practice of measurement and control and the design and implementation of experiments. Topics include dimensional analysis, error analysis, signal-to-noise problems, filtering, data acquisition and data reduction, and statistical analysis. Includes experiments on the use of electronic devices and sensors and practice in technical report writing.
ME170B	4	Experimental Techniques	Prerequisite(s): ME 103, ME 110, ME 113, ME 116A, ME 170A. Analysis and verification of engineering theory using laboratory measurements in advanced, project-oriented experiments involving fluid flow, heat transfer, structural dynamics, thermodynamic systems, and electromechanical systems.
ME174	4	Machine Design	Prerequisite(s): ME 009, ME 103 (can be taken concurrently), ME 110, ME 114. An introduction to the fundamentals of strength-based design. Topics include deflection and stiffness, static failure, and fatigue failure.
ME176	4	Sustainable Product Design	Prerequisite(s): ME 103, ME 110, ME 113, ME 116A. Introduces the principles of sustainable product design. Topics include life cycle design; design for reliability, maintainability, and recycling/reuse/remanufacture; materials selection; and manufacturing processes. Includes project in which students analyze the environmental impact of a product and redesign it to reduce the impact. Credit is awarded for only one of ME 176 or ME 210.
ME180	4	Optics and Lasers in Engineering	Prerequisite(s): EE 005, MATH 010B; or equivalent; or consent of instructor. Introduces basic principles of optics and lasers, wave equations, interferometry, diffraction, Fourier optics, light-matter interactions, ultrafast and nonlinear optics, and nanophotonics. Frames introductory concepts with experimental design and computer analysis. Includes applications and analytical exercises with microscopy and spectroscopy, smart-phone camera hacks, thin-film and bulk materials characterization, and communication systems. Credit is awarded for one of the following ME 180 or ME 280.

Chemical and Environmental Engineering (CEE)

		Lower Division	
CEE010	1	Introduction to Chemical and Environmental Engineering	Prerequisite(s): none. An introduction to chemical and environmental engineering for engineering and nonengineering majors. Aims to enrich an appreciation of chemical, biochemical, and environmental engineering. Discusses typical careers, key applications, latest developments and the need to engage in lifelong learning in the field. Graded Satisfactory (S) or No Credit (NC).
CEE011	2	Introduction to Bioengineering	An introduction to bioengineering for engineering and nonengineering majors. Discusses the application of concepts and methods of the physical sciences and mathematics to problems in the life sciences. Covers typical careers, key applications, latest developments in the field, and the need to engage in lifelong learning. Provides hands-on experiences and includes a field trip. Graded Satisfactory (S) or No Credit (NC).
		Upper Division	
CEE125	4	Analytical Methods For Chemical and Environmental Engineers	Prerequisite(s): CEE 010 (CEE 010 may be taken concurrently); CHEM 001C and CHEM 01LC; CHEM 008A and CHEM 08LA or CHEM 08HA and CHEM 08HLA; PHYS 040C or PHYS 040HC. Examines chromatographic separations, mass spectrometry, atomic absorption, and electrophoresis. Presents total carbon analysis as an introduction to analytical methods and their use in the chemical and environmental engineering fields.
CEE132	4	Green Engineering	Prerequisite(s): CHE 110A or ENVE 171, senior standing or consent of instructor. An introduction to the design, commercialization, and use of feasible and economical processes and products that minimize risks to human health and the environment. Topics covered include environmental risk assessment; regulations; chemical process flow-sheet analysis for pollution prevention; product life-cycle assessment; and industrial ecology. Credit is awarded for only one of CEE 132 or CEE 232.
CEE135	4	Chemistry of Materials	Prerequisite(s): CHEM 008A and CHEM 08LA or CHEM 08HA and CHEM 08HLA; PHYS 040C or PHYS 040HC. An introduction to the synthesis, structure, properties, and performance of modern materials. Topics include the science of materials, bonding and structure, the strength of materials, electrons in materials, semiconductors, superconductors, and optical properties of materials.
CEE136	4	Aerosol Technology	Prerequisite(s): concurrent enrollment in CHE 120. Explores the physical and chemical properties of aerosol and its relationship to ambient air quality, control technology, health impacts, and global climate change. Introduces the principles of aerosol measurement and aerosol measurement technology
CEE140A	4	Biomaterials	Prerequisite(s): BIEN 101 or BCH 100, MATH 010B, PHYS 040B or PHYS 040HB; or consent of instructor. Covers the principles of materials science and engineering, with attention to topics in bioengineering. Explores atomic structures, hard treatment, fundamentals of corrosion, manufacturing processes, and characterization of materials. Cross-listed with BIEN140A.
CEE140B	4	Biomaterials	Prerequisite(s): PHYS 040B or PHYS 040HB; Covers the structure-property relations of metals, ceramics, polymers, and composites, as well as hard and soft tissues such as bone, teeth, cartilage, ligament, skin, muscle, and vasculature. Focuses on behavior of materials in the physiological environment. Cross-listed with BIEN140B.
CEE159	4	Dynamics of Biological Systems	Prerequisite(s): BIOL 005B, MATH 046; or consent of instructor. Covers engineering principles for the analysis and modeling of biological phenomena. Topics include molecular diffusion and transport, membranes, ligand-bioreceptor interactions, enzyme kinetics, and dynamics of metabolic pathways. Examines the application of these principles to the design of bioreactors, bioassays, drug delivery systems, and artificial organs. Cross-listed with BIEN 159.
CHE100	4	Engineering Thermodynamics	Prerequisite(s): CHEM 001C, MATH 046 (or concurrent enrollment), PHYS 040B or PHYS 040HB; or consent of instructor. An introduction to engineering thermodynamics with emphasis on chemical and environmental engineering systems. Topics include concepts of equilibrium, temperature, and reversibility; the

			first law and concept of energy; and the second law and concept of entropy. Also examines equations of state, thermodynamic properties, and engineering applications used in the analysis and design of closed and open systems. Credit is awarded for only one of CHE 100 or ME 100A.
CHE102	4	Catalytic Reaction Engineering	Prerequisite(s): CHE 122 or consent of instructor. Principles of surface reactions and heterogeneous catalysis. Catalyzed reaction kinetics, heterogeneous reactions, diffusion and heterogeneous catalysis, analysis and design of heterogeneous reactors.
CHE105	4	Introduction to Nanoscale Engineering	Prerequisite(s): CEE 135, MATH 010A, PHYS 040C or PHYS 040HC; or consent of instructor. An introduction to nanotechnology engineering and its various applications. Includes electromagnetic waves and quantum mechanics; synthesis of nanostructures; assembly of nanostructures; and traditional and nontraditional methods of nanolithography and interactions between electronic and optical properties. Also covers organic heterostructures, nanotubes, and quantum computing
CHE110A	3	Chemical Process Analysis	Prerequisite(s): CHEM 001C, MATH 009C, PHYS 040B or PHYS 040HB; or consent of instructor. Introduces the principles of conservation of mass in chemical process systems. Topics include the development of steady-state mass balances, and application of mass balances to existing industrial processes.
CHE110B	3	Chemical Process Analysis	Prerequisite(s): CHE 110A with a grade of "C-" or better; or consent of instructor. Applies principles of conservation of energy to chemical process systems. Topics include the development of steady-state and unsteady state energy balances as well as combined mass and energy balances in industrial processes.
CHE114	4	Applied Fluid Mechanics	Prerequisite(s): CHE 110A or ENVE 171, MATH 010A, MATH 046, PHYS 040B or PHYS 040HB; or consent of instructor. An introduction to fluid statics, fluid flow, and flow of compressible and incompressible fluids in conduits and open channel flow. Also covers flow past immersed bodies, transportation and metering of fluids, and agitation and mixing of liquids. Credit is awarded for only one of CHE 114 or ME 113.
CHE116	4	Heat Transfer	Prerequisite(s): CHE 100, CHE 114 with a grade of "C-" or better; or consent of instructor. An analysis of heat transfer for Chemical Engineering and Environmental Engineering majors. Topics include steady- and unsteady-state heat conduction, forced convection, basic radiation heat transfer, and design of heat exchangers. Credit is awarded for only one of CHE 116 or ME 116A.
CHE117	4	Separation Processes	Prerequisite(s): CHE 116, CHE 120; or consent of instructor. Covers fundamental concepts and practical techniques for designing equipment based on equilibrium stage processes. Explores gas-liquid absorption, distillation, liquid-liquid extraction, solid liquid extraction, humidification, drying, and membrane processes.
CHE118	4	Process Dynamics and Control	Prerequisite(s): CHE 117, CHE 122, ENGR 118; or consent of instructor. Fundamentals of process control. Feedback and feedforward control of dynamic processes. Frequency response analysis. Introduction to multivariable control.
CHE120	4	Mass Transfer	Prerequisite(s): CHE 114 with a grade of "C-" or better, MATH 046; or consent of instructor. Introduction to analysis of mass transfer in systems of interest to chemical and environmental engineering practice. Explores transport of matter by diffusion, free, and forced convection.
CHE122	4	Chemical Engineering Kinetics	Prerequisite(s): CHE 100, CHE 110B, CHE 120 (may be taken concurrently), ENGR 118; or consent of instructor. Introduction to homogeneous and heterogeneous kinetics and reactor design for chemical and biochemical processes.
CHE124	2	Biochemical Engineering Principles	Prerequisite(s): BCH 110HA or BCH 110A; CHE 120, CHE 122. Examines the principles of biochemical engineering. Topics include kinetics of enzymatic reactions and robial growth, batch and continuous culture reactors, product formulation, and nutrient utilization. Also studies oxygen transfer, bioreactor scaleup, air and media sterilization, fundamentals of bioreactor design, and bio separations.
CHE124L	4	Biochemical Engineering Laboratory	Prerequisite(s): CHE 124 or consent of instructor. Laboratory practices in biochemical engineering. Determination of microbial kinetics and biologically mediated reactions, oxygen transfer coefficients. Batch and continuous culturing, air and media sterilization, bio separations.
CHE/ENVE130	4	Advanced Engineering Thermodynamics	Prerequisite(s): CHE 100 or consent of instructor. Advanced study of chemical thermodynamics and their applications to chemical and environmental engineering ocesses. Applies principles for the thermodynamic behavior of pure solutions and mixtures, phases, and chemical equilibria for homogeneous and heterogeneous systems to a variety of processes common to chemical and environmental engineering. Cross-listed with ENVE 130.

CHE131	4	Electrochemical Engineering	Prerequisite(s): CHE 100, CHE 120, CHE 122; or consent of instructor. Explores role of thermodynamics, charge transfer kinetics, and mass transfer on behavior of rochemical systems. Includes cell thermodynamics, faradaic and non-faradaic rate processes, ionic transport, nucleation and growth theories. Shows applications to chemical sensors, batteries, corrosion, and thin film deposition. Provides in-class demonstrations to illustrate concepts.
CHE136	4	Advanced Topics in Heat Transfer	Prerequisite(s): CHE 116, CHE 120. Advanced study of the computational and theoretical methods associated with heat transfer, fluid flow, and other related processes. Topics include phenomena of heat conduction, convection, and the calculation of flow fields.
CHE140	4	Cell Engineering	Prerequisite(s): CHE 124 or consent of instructor. Introduction to genetic and environmental manipulation of cells for production of proteins and for enhanced biocatalytic and synthetic activities. Cloning and gene expression in different host systems, posttranslational processing, metabolic controls and kinetics, in vivo NMR spectroscopy, cell modeling, and sensitivity analysis. Credit is awarded for only one of CEE 210 or CHE 140.
CHE150	4	Biosensors	Prerequisite(s): BCH 184 or CHE 124 or consent of instructor. Introduces the fundamentals and applications of biosensors. Topics on enzyme-, whole cell-, tissue-, and antibody/antigen-based electrochemical, optical, and piezoelectric biosensors for applications in bioprocess monitoring and control, environmental monitoring, and health care are covered.
CHE/ENVE160A	3	Chemical and Environmental Engineering Laboratory	Prerequisite(s): CHE 114; CHE 120. Involves laboratory exercises in chemical and environmental engineering. Experiments cover physical measurements, fluid mechanics, and mass transfer. Emphasizes experimental design, analysis of results, and preparation of engineering reports. Cross-listed with ENVE 160A.
CHE/ENVE160B	3	Chemical Engineering Laboratory	Prerequisite(s): CHE 116; CHE 122. Consists of laboratory exercises in chemical engineering. Includes experiments in physical measurements, heat transfer, reactor analysis, and chemical kinetics. Emphasizes experimental design, analysis of results, and preparation of engineering reports.
CHE/ENVE160C	3	Chemical Engineering Laboratory	Prerequisite(s): CHE 122; CHE 117, may be taken concurrently; CHE 118, may be taken concurrently; or consent of instructor. Consists of laboratory exercises in chemical engineering. Includes experiments and simulations in separation processes and in process control. Emphasizes experimental design, analysis of results, and preparation of engineering reports.
CHE161	3	Nanotechnology Processing Laboratory	Prerequisite(s): CHE 100 or consent of instructor. An introduction to growth and characterization techniques that involve nanomaterials and devices. Includes preparing thin films; synthesizing Au and CdS nanoparticles; synthesizing carbon nanotubes; synthesizing alumina nano template; synthesizing gold and nickel nanowires; and assembling of nanowires. Also includes imaging samples with optical, scanning electron microscope, scanning tunneling microscope, and atomic force microscope.
CHE171	4	Pollution Control For Chemical Engineers	Prerequisite(s): CHE 117 or consent of instructor. Principles of industrial pollution control in chemical engineering plants. Regulations, criteria, measurements, and pollution control systems associated with air, wastewater, and solid waste management.
ENVE120	4	Unit Operations and Processes in Environmental Engineering	Prerequisite(s): CHE 120, ENVE 142; or consent of instructor. Introduction to physical and chemical processes used for drinking water and wastewater treatment. Topics include coagulation and flocculation, sedimentation, granular-medium filtration, membrane disinfection, and softening. Credit is awarded for only one of CEE 225 or ENVE 120.
ENVE121	4	Biological Unit Processes	Prerequisite(s): ENVE 120, ENVE 142 An introduction to the theory and design of biological unit processes used in environmental engineering. Covers suspended growth processes, attached growth processes, digestion processes, and nutrient removal systems. Credit is awarded for only one of CEE 226 or ENVE 121.
ENVE133	4	Fundamentals of Air Pollution Engineering	Prerequisite(s): CHE 110A or ENVE 171; CHE 114; MATH 046; PHYS 040B or PHYS 040HB; CHEM 008A, may be taken concurrently or CHEM 08HA, may be taken concurrently; or consent of instructor. Covers principles, modeling, and design of systems for atmospheric emission control of pollutants such as photochemical smog and by-products of combustion. Explores the effects of air pollution on health.
ENVE134	4	Technology of Air Pollution Control	Prerequisite(s): ENVE 133. Processes and design of control technologies for gaseous and particulate pollutants. Methods and design of ambient air quality measurements and air pollution source sampling for both gaseous and particulate pollutants.

ENVE135	4	Fate and Transport of Environmental Contaminants	Prerequisite(s): CHE 120; CHEM 008B and CHEM 08LB or CHEM 08HB and CHEM 08HLB; ENGR 118; ENVE 133; ENVE 142; or consent of instructor. Covers fate and transport of contaminants in the air, water, and soil environments. Addresses description and modeling of advection, dispersion, phase transfer, and chemical transformation mechanisms.
ENVE138	4	Combustion Engineering	Prerequisite(s): CHE 114, ENVE 133. Covers the fundamental development of the engineering and design principles underlying combustion engines and turbines and the associated emission control technology. Includes aspects of fuels, lubricants, instrumentation, chemistry of combustion, and kinetics related to the understanding of engineering processes, engine design, and emission control.
ENVE140	4	Aquatic Chemistry	Prerequisite(s): CHE 100, ENVE 142; or consent of instructor. An introduction to the chemical principles and equilibrium models used to describe the behavior of natural water systems, water and wastewater treatment processes, and pollutant transformations in the aqueous environment. Topics include acid-base chemistry, precipitation, complexation, and redox reactions. Credit is awarded for only one of CEE 241 or ENVE 140.
ENVE142	4	Water Quality Engineering	Prerequisite(s): CHE 114 or ENVE 171; or consent of instructor. An introduction to the engineering aspects of water quality management. Addresses water quality characterization and modeling techniques for natural and engineered systems. Discusses application of chemical equilibrium and kinetic models to water quality
ENVE144	4	Solid Waste Management	Prerequisite(s): BIOL 002 or BIOL 005A, BIOL 05LA; CHEM 001C, CHEM 01LC or CHEM 01HC, CHEM 01HLC; ENSC 001, ENSC 002 or ENVE 171; MATH 007B or MATH 009B or MATH 09HB; or consent of instructor. A study of the characterization, collection, transportation, processing, disposal, recycling, and composting of municipal solid waste. Emphasizes accepted management strategies and design procedures for recovering or disposing solid wastes while protecting public and environmental wellbeing. Cross-listed with ENSC 144.
ENVE145	4	Hazardous Waste Management	Prerequisite(s): ENVE 120 and ENVE 142. Advanced course in the study of physiochemical, thermal, and biological treatment of hazardous waste. Emphasis is placed on the technical understanding and design of physical, biological, and thermal treatment methods; transportation of hazardous waste; and hazardous waste characterization and site assessment.
ENVE146	4	Water Quality Systems Design	Prerequisite(s): CHE 114 or consent of instructor. Analysis and design of water conveyance systems including water distribution networks, wastewater and storm water collection systems, structures for flow measurement and control, and pumps and pump stations. Includes projects to develop design process skills including problem specification, modeling, and analysis.
ENVE171	4	Fundamentals of Environmental Engineering	Prerequisite(s): CHEM 001C, MATH 009C, PHYS 040B or PHYS 040HB; or consent of instructor. An introduction to mass and energy balances. Includes an overview of contaminants and their effects on human health and the environment. Provides a basic understanding of contaminants, their sources, and their movement and fate in the environment.

Bioengineering (BIEN)

Lower Division			
BIEN010	4	Overview of Bioengineering	Provides an overview of the various aspects of bioengineering and introduces bioengineering design. Illustrates the application of engineering principles for the design of various products to health science industries. Covers diagnostic instruments, artificial organs, biotechnology, and cell and tissue engineering. Covers engineering ethics
Upper Division			
BIEN101	4	Quantitative Biochemistry	Prerequisite(s):BIOL 005A; CHEM 008A and CHEM 08LA or CHEM 08HA and CHEM 08HLA; MATH 046. Provides Bioengineering students with an in-depth experience in applying mathematical modeling and simulation methods to understand the dynamics of biochemical systems. Prepares for designing new applications of genetic engineering.
BIEN105	4	Circulation Physiology	Prerequisite(s): BIEN 110. Introduces tensor and vector mathematics that describe the conservation of momentum and mass transport in biological sciences, the cardiovascular system, and pulmonary system. Includes constitutive equations, significance of fluid stress in biological vessels, and the physiological relevance of fundamental parameters. Emphasizes the relation between function and system behavior.
BIEN110	4	Biomechanics of the Human Body	Prerequisite(s): CHEM 001C or CHEM 01HC; CS 010A; MATH 010A; PHYS 040B or PHYS 040HB. Introduces the motion, structure, and function of the musculoskeletal system, the cardiovascular system, and the pulmonary system. Topics include applied statics, kinematics, and dynamics of these systems and the mechanics of various tissues (ligament, bone, heart, blood vessels, lung). Emphasizes the relation between function and material properties of these tissues.
BIEN115	4	Quantitative Physiology	Prerequisite(s): BIEN 110; consent of instructor is required for non-majors. Analyzes engineering aspects of physiological systems. Covers the nervous system, muscular system, respiratory system, renal system, and endocrine system based on fundamental principles of material transport across biological membrane.
BIEN120	4	Biosystems and Signal Analysis	Prerequisite(s): BIEN 105. Provides basic knowledge for the quantitative analysis of the dynamic behavior of biological systems. Particular applications include neural systems, control of metabolic and hormonal systems, and design of instruments for monitoring and controlling biological systems. Topics include system theory, signal properties, control theory, and transfer functions.
BIEN125	4	Biotechnology and Molecular Bioengineering	Prerequisite(s): BIEN 101. Provides an overview of biochemical processes in cells and their use in developing new products and processes. Presents cellular processes such as metabolism, protein synthesis, enzyme behavior, and cell signaling and control from an engineering viewpoint of modeling and control.
BIEN130	4	Bioinstrumentation	Prerequisite(s): concurrent enrollment in BIEN 130L; EE 005 with a grade of C- or better. Introduces basic components of instruments for biological applications. Explores sources of signals and physical principles governing the design and operation of instrumentation systems used in medicine and physiological research. Topics include data acquisition and characterization; signal-to-noise concepts and safety analysis; and interaction of instrument and environment.
BIEN130L	2	Bioinstrumentation Laboratory	Prerequisite(s): concurrent enrollment in BIEN 130; EE 005 with a grade of C- or better. Provides a laboratory experience with instrumental methods of measuring biological systems. Introduces various sensors and transducers to measure physical, chemical, and biological properties. Covers reliability, dynamic behavior, and data analysis.
BIEN135	4	Biophysics and Biothermodynamics	Prerequisite(s): BIEN 101, MATH 10B, MATH 046, PHYS 040C or PHYS 040HC. An introduction to the application of thermodynamic principles to understanding the behavior of biological systems. Discusses biophysical properties of biomacromolecules such as proteins, polynucleotides, carbohydrates, and lipids, as well as the methods of characterizing their properties and interactions.

BIEN136	4	Tissue Engineering	Prerequisite(s): BIOL 005B; CHEM 001C or CHEM 01HC; BIEN 140A or CEE 140A; restricted to class level standing of junior, or senior; or consent of instructor. Covers progress in cellular and molecular biology and engineering. Provides the basis for advancing tissue repair and regeneration with the goal of restoring compromised tissue functions. Presents methods for cell culture, tissue design and development, manipulation of the cell/tissue microenvironment, and current strategies for functional reconstruction of injured tissues. Cross-listed with MSE 136.
BIEN137	4	Advanced Biomechanics	Prerequisite(s): BIEN110, BIOL 005B, MATH 046, PHYS 040A or equivalents; or consent of instructor. Focuses on mechanical characterization of biological tissues at the cellular, organ, and system level. Explores biomechanical factors of physiological and pathological conditions.
BIEN138	4	Fundamental Principles of Wound Repair	Prerequisite(s): BIEN 105, BIOL 002 or BIOL 005A, or equivalents; or consent of instructor. Provides fundamental understanding of the molecular and cellular biology of wound repair and regeneration. Focuses on the spatiotemporal roles of inflammatory cytokines; growth factors; extracellular matrix; mechanical forces; tissue cells and adult stem/progenitor cells in soft tissue repair. Topics include embryonic wound regeneration and adult skin and cardiovascular repair.
BIEN140A	4	Biomaterials	Prerequisite(s): BIEN 101 or BCH 100, MATH 010B, PHYS 040B or PHYS 040HB; or consent of instructor. Covers the principles of materials science and engineering with attention given to topics in bioengineering. Explores atomic structures, hard treatment, fundamentals of corrosion, manufacturing processes, and characterization of materials. Cross-listed with CEE 140A.
BIEN140B	4	Biomaterials	Prerequisite(s): PHYS 040B or PHYS 040HB. Covers the structure-property relations of metals, ceramics, polymers, and composites, as well as hard and soft tissues such as bone, teeth, cartilage, ligament, skin, muscle, and vasculature. Focuses on behavior of materials in the physiological environment. Cross-listed with CEE 140B.
BIEN142	4	Introductory Biomedical Optical Imaging	Prerequisite(s): PHYS 040C or PHYS 040HC; and MATH 010B; or consent of instructor. Examines fundamental theory and basic design of biomedical optical imaging systems. Topics include a basic understanding of the working principles of optical components, diagnostic light-tissue interaction, and design of imaging systems to exploit the interaction of light with biological phenomena.
BIEN155	2	Biotechnology Laboratory	Prerequisite(s): concurrent enrollment in BIEN 175A or a grade of “C-”or better in BIEN 175A; BIEN 101, BIEN 125. Laboratory experience in cell culture, bioreactors, optical techniques, array techniques, and separation and purification methods.
BIEN159	4	Dynamics of Biological Systems	Prerequisite(s): BIOL 005B, MATH 046; or consent of instructor. Covers engineering principles for the analysis and modeling of biological phenomena. Topics include molecular diffusion and transport, membranes, ligand-bioreceptor interactions, enzyme kinetics, and dynamics of metabolic pathways. Examines the application of these principles to the design of bioreactors, bioassays, drug delivery systems, and artificial organs. Cross-listed with CEE 159.
BIEN160	4	Biomedical Imaging	Prerequisite(s): BIEN 120. An introduction to the fundamental physics and engineering principles for medical imaging systems. Covers X-ray, ultrasound, radionuclide, magnetic resonance imaging, positron emission tomography, optical coherent tomography, and other optical methods. Includes image formation and reconstruction, image characteristics, and quality and image processing.
BIEN165	4	Biomolecular Engineering	Prerequisite(s): BIEN 135, or consent of instructor. Emphasizes engineering, biochemical, and biophysical concepts and technologies intrinsic to specific topics of biomolecular engineering. Introduces the history of genetic and protein engineering. Topics include biological thermodynamics, molecular kinetics, biochemical and biophysical approaches, protein engineering, high-throughput screening technologies, and protein engineering with unnatural amino acids.
BIEN166	4	Bioinspired Engineering For Sustainable Energy	Prerequisite(s): BIEN 140A/CEE 140A Introduces the use of concepts from basic biological sciences (including biochemistry and biophysics) for applied energy engineering. Covers biological energy conversion (including photosynthesis) and its implication for sustainable energy technologies. Discusses recent advances in biomimetic and bioinspired energy conversion.

BIEN167	4	Medical Diagnostics	Prerequisite(s): BIEN 130 or consent of instructor. Provides an overview of medical diagnostics. Topics include methods of biochemical detection, genotyping, DNA sequencing, medical imaging, hematology, microfluidics, epidemiology, diagnostics for point-of-care and resource limited settings, and case studies of commercially successful diagnostic products.

Materials Science and Engineering (MSE)

		Lower Division	
MSE001	1	Fundamentals of Materials Science and Engineering	Prerequisite(s): none. An introduction of properties and applications of different types of materials essential for various areas of engineering. Explores the relationship between structure and properties as well as processing of the materials. Illustrates a wide range of properties required for different types of applications. Graded Satisfactory (S) or No Credit (NC).
MSE002L	1	General Materials Laboratory Spring	Prerequisite(s): MSE 001 with a grade of C- or better; restricted to major(s) Materials Science and Engineer; or consent of instructor. Provides hands-on laboratory experience in topics related to the Structure-Composition-Processing Performance relationship of ceramics, electronic materials, metals, and polymers. Experiments cover mechanical testing and properties of different materials classes and introduce students to microscopic characterization techniques. Satisfactory(S) or No Credit(N/C) is not available
MSE003L	1	General Materials Laboratory Fall	Prerequisite(s): MSE 001 with a grade of C- or better; restricted to major(s) Materials Science and Engineer; or consent of instructor. Provides hands-on laboratory experience in topics related to the Structure-Composition-Processing Performance relationship of ceramics, electronic materials, metals, and polymers. Experiments cover materials processing and failure modes of different materials classes. Satisfactory(S) or No Credit(N/C) is not available.
MSE004L	1	General Materials Laboratory Winter	Prerequisite(s): MSE 001 with a grade of C- or better; restricted to major(s) Materials Science and Engineer; or consent of instructor. Provides hands-on laboratory experience in topics related to the Structure-Composition-Processing Performance relationship of ceramics, electronic materials, metals, and polymers. Experiments cover electrical, thermal, optical, and magnetic properties. Introduces composites and the factors that affect its properties and mechanical performance. Satisfactory(S) or No Credit(N/C) is not available.
		Upper Division	
MSE134	4	Microstructural Transformations in Materials	Prerequisite(s): ME 114 or consent of instructor. An introductory study of the fundamentals (thermodynamics and kinetics) controlling microstructural transformations in materials and their application to both liquid solid and solid-solid transformations. Focuses on the important transformations that ultimately control the microstructures and properties of crystalline solids. Cross-listed with ME 134.
MSE135	4	Introduction to Inorganic Material Synthesis	Prerequisite(s): MSE 001, CHE 100, ME 114, CHEM 008A; or consent of instructor. Introduction to the synthesis methods of modern materials. Topics include solid-state reactions, gas-phase and solution phase synthesis, templating methods, synthesis and modification of inorganic polymers, semiconductor thin-film deposition, and the growth of nanomaterials.
MSE136	4	Tissue Engineering	Prerequisite(s): BIOL 005B; CHEM 001C or CHEM 01HC; BIEN 140A or CEE 140A; restricted to class level standing of junior, or senior; or consent of instructor. Covers progress in cellular and molecular biology and engineering. Provides the basis for advancing tissue repair and regeneration with the goal of restoring compromised tissue functions. Presents methods for cell culture, tissue design and development, manipulation of the cell/ tissue microenvironment, and current strategies for functional reconstruction of injured tissues. Cross-listed with BIEN 136.

MSE142	4	Corrosion Science	Prerequisite(s): MSE 134; restricted to class level standing of senior; or consent of instructor. Introduces the principles of corrosion in metals and alloys. Discusses the relevant elements of electrochemistry, electrochemical corrosion, thermodynamics, and the kinetic aspects of corrosion. Includes projects that provide practical hands-on experience using state-of the-art computational techniques in materials science. Credit is awarded for one of the following MSE 142 or MSE 233A.
MSE143	4	Failure Analysis and Prevention	Prerequisite(s): ME 114 with a grade of C or better; restricted to class level standing of senior; or consent of instructor. Topics include failure modes due to overload, fatigue, fracture, and creep. Also addresses statistical analysis, probability of failure, quality assurance, and elements of fracture mechanics. Cross-listed with ME 157. Credit is awarded for one of the following ME 157, MSE 143, or MSE 233B.
MSE148	4	Advanced Solidification Processing	Prerequisite(s): MSE 143 or ME 157; restricted to class level standing of senior; or consent of instructor. An overview of the fundamentals of solidification processing. Includes integrated interplay of heat flow, mass transport, and solid/liquid interfacial kinetics during discontinuous change of state from liquid to solid of single phase and polyphase materials. Cross-listed with ME 158. Credit is awarded for one of the following MSE 148, ME 158, ME 279, or MSE 248C.
MSE155	4	Materials Science of the Solid State	Prerequisite(s): EE 138. Explores at an advanced level the quantum mechanical behavior of electron motion and atom vibration in a periodic solid and their effect on the electronic and thermal properties of matter. The course discusses modern materials science research problems. Credit is awarded for one of the following MSE 155 or MSE 211
MSE156	4	Atomistic Modeling of Solid State Materials	Prerequisite(s): MSE 155; restricted to class level standing of senior; or consent of instructor. Introduces a basic understanding of computational methods in materials science. Emphasizes the fundamentals of density functional theory and its use in the solid-state context. Includes projects that provide practical hands-on experience using state-of-the art computational techniques in materials science. Credit is awarded for one of the following MSE 156 or MSE 224.
MSE160	4	Nanostructure Characterization Laboratory	Prerequisite(s): ME 114. Covers structure of materials at the nanoscale, including semiconductors, ceramics, metals, and carbon nanotubes. Explores relationships among morphology, properties, and processing. Addresses primary methods of characterization, including scanning electron microscopy, scanning probe microscopy, X-ray diffraction, and transmission electron microscopy. Also covers elementary discussions of X-ray, vibrational, and electron waves in solids and introductory diffraction theory.
MSE161	4	Analytical Materials Characterization	Prerequisite(s): MSE 160. Analysis of the surfaces of materials via ion, electron, and photon spectroscopies. Covers Rutherford back scattering; secondary ion mass spectroscopy; electron energy loss spectroscopy; Auger electron spectroscopy; X-ray photoelectron spectroscopy; photoluminescence; extended X-ray absorption fine structure; Fourier transform infrared spectroscopy; Raman spectroscopy; sputtering; high-vacuum generation; and focused ion beam milling. Cross-listed with EE 161.

Data Science (DTSC)

Upper Division			
STAT155	4	Probability and Statistics For Science and Engineering	Prerequisite(s): MATH 009C, may be taken concurrently or MATH 09HC, may be taken concurrently. Covers sample spaces and probability; random variables and probability distributions; elements of statistical inference; and testing and estimation. Also addresses selected topics in multivariate distributions and introduces stochastic processes. Credit is not awarded for STAT 155 if it has already been awarded for STAT 156A or STAT 160A
STAT156A	4	Mathematical Statistics With Applications For Data Science	Prerequisite(s): MATH 009C with a grade of C- or better or MATH 09HC. Introduction to frequentist probability concepts, random variables, and their distributions. Discusses key theorems and inequalities in probability theory. Introduces to frequentist methods of point and interval estimation. Credit is awarded for one of the following STAT 156A or STAT 160A.

STAT156B	4	Mathematical Statistics With Applications For Data Science II	Prerequisite(s): STAT 156A with a grade of C- or better. Topics include illustrative applications of Frequentist theory to linear regression; logistic regression and ANOVA; introduction to Bayes' rule, Bayesian probability concepts, and credible intervals; analysis of contingency tables; applications of sequential statistics; and methods for observational studies and missing data. Credit is awarded for one of the following STAT 156B or STAT 160B.
STAT167	4	Introduction to Data Science	Prerequisite(s): STAT 107 with a grade of C- or better; CS 009A with a grade of C- or better or CS 010A with a grade of C- or better. Introduction to data science using the R programming language. Topics include big data management, visualization and analytical skills, unsupervised and supervised statistical learning methods, and real-world data science application examples.
CS105	4	Data Analysis Methods	Prerequisite(s): CS 009B with a grade of C- or better or CS 010B with a grade of C- or better; restricted to class level standing of sophomore, junior, senior, or masters. An introduction to fundamental concepts and methods in data analysis and visualization essential to a variety of data science tasks. Designed to provide preparation for the data science major and for advanced courses in data analysis and applications of data science.