Kenneth Heafield

Language Technologies Institute <r at kheafield.com>
Carnegie Mellon University http://kheafield.com
5000 Forbes Ave NSH 4502
Pittsburgh, PA 15213

This document includes course descriptions taken from the catalog. A shorter version, with only course titles, and my resume are available at http://kheafield.com/professional/. P means passing.

Code	Title	Year	Grade
	Carnegie Mellon PhD		
10 701	Machine Learning	Gr1	A

It is hard to imagine anything more fascinating than automated systems that improve their own performance. The study of learning from data is commercially and scientifically important. This course is designed to give a graduate-level student a thorough grounding in the methodologies, technologies, mathematics and algorithms currently needed by people who do research in learning and data mining or who may need to apply learning or data mining techniques to a target problem. The topics of the course draw from classical statistics, from machine learning, from data mining, from Bayesian statistics and from statistical algorithmics. Students entering the class should have a pre-existing working knowledge of probability, statistics and algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate.

11 711	Algorithms for NLP	Gr1	A

Algorithms for NLP is an introductory graduate-level course on the computational properties of natural languages and the fundamental algorithms for processing natural languages. The course will provide an in-depth presentation of the major algorithms used in NLP, including Lexical, Morphological, Syntactic and Semantic analysis, with the primary focus on parsing algorithms and their analysis.

11 910	Directed Research	Gr1	

Comment: Half my time each semester is spent working for my adviser Alon Lavie on Multi-Engine Machine Translation.

15 295	Competition Programming and Problem Solving	Gr1	A

Each year, Carnegie Mellon fields two teams for participation in the ACM-ICPC Regional Programming Contest. During many recent years, one of those teams has earned the right to represent Carnegie Mellon at the ACM-ICPC World Finals. This course is a vehicle for those who consistently and rigorously train in preparation for the contests to earn course credit for their effort and achievement. Preparation involves the study of algorithms, the practice of programming and debugging, the development of test sets, and the growth of team, communication, and problem solving skills. Neither the course grade nor the number of units earned are dependent on ranking in any contest. Students are not required to earn course credit to participate in practices or to compete in ACM-ICPC events. Consistent, disciplined participation in team practices and associated individual preparation earns three (3) units of credit. Six (6) units of credit are possible for those who routinely complete significant homework and/or teamwork assignments outside of normal group meetings. Students interested in the course should attend during the first week of classes to discuss enrollment details.

Code	Title	Year	Grade
	Caltech BS Computer Science and Math		
CS 11	Computer Language Shop	Fr, Jr, Sr	P P P

CS 11 is a self-paced lab that provides students with extra practice and supervision in transferring their programming skills to a particular programming language; the course can be used for any language of the student's choosing, subject to approval by the instructor. A series of exercises guide the student through the pragmatic use of the chosen language, building his or her familiarity, experience, and style. More advanced students may propose their own programming project as the target demonstration of their new language skills. Lab staff will critique the student's technique and craftsmanship, offering expert feedback on areas for attention and helping the student with any conceptual difficulties that may arise while mastering the particular language. CS 11 may be repeated for credit of up to a total of 9 units.
Comment: This was not taken to learn a language but to participate in the International Collegiate Programming Contest.

CS 21	Decidability and Tractability	Fr	P

This course introduces the formal foundations of computer science, the fundamental limits of computation, and the limits of efficient computation. Topics will include automata and Turing machines, decidability and undecidability, reductions between computational problems, and the theory of NP-completeness.

CS 24	Introduction to Computing Systems	So	A-

Basic introduction to computer systems, including hardware-software interface, computer architecture, and operating systems. Course emphasizes computer system abstractions and the hardware and software techniques necessary to support them, including virtualization (e.g., memory, processing, communication), dynamic resource management, and common-case optimization, isolation, and naming.

CS 38	Introduction to Algorithms	So	A-

This course introduces techniques for the design and analysis of efficient algorithms. Major design techniques (the greedy approach, divide and conquer, dynamic programming, linear programming) will be introduced through a variety of algebraic, graph, and optimization problems. Methods for identifying intractability (via NP-completeness) will be discussed.

CS 90	Undergraduate Research in Computer Science	Jr	P P

Supervised research in computer science by undergraduates. Topic must be approved by the supervisor, and a formal final report must be presented on completion of research. Graded pass/fail.
Comment: For two terms, I worked under Professor Steven Low to extend Kernel Principal Component Analysis and test the validity of these extensions, a continuation of my summer research.

CS/EE/Ma 129ab	Information and Complexity	Sr	A A

A basic course in information theory and computational complexity with emphasis on fundamental concepts and tools that equip the student for research and provide a foundation for pattern recognition and learning theory. First term: what information is and what computation is; entropy, source coding, Turing machines, uncomputability. Second term: topics in information and complexity; Kolmogorov complexity, channel coding, circuit complexity, NP-completeness. Third term: theoretical and experimental projects on current research topics.

Code	Title	Year			Grade
CS 141abc	Distributed Computation Laboratory	Jr	A	A-	A+

This laboratory course deals with the systematic design and implementation of high-confidence scalable networks of communicating objects that discover other objects, configure themselves into collaborating groups of objects, and adapt to their environment. Teams of students explore theories and methods of implementation to obtain predictability and adaptability in distributed systems. Each team of students is expected to submit a research paper at the end of the third term, schedule demonstrations periodically, and maintain documents describing their project status.

EE/Ma 126ab	Information Theory	Sr		A-	A-

Shannon's mathematical theory of communication, 1948-present. Entropy, relative entropy, and mutual information for discrete and continuous random variables. Shannon's source and channel coding theorems. Mathematical models for information sources and communication channels, including memoryless, first-order Markov, ergodic, and Gaussian. Calculation of capacity-cost and rate-distortion functions. Kolmogorov complexity and universal source codes. Side information in source coding and communications. Network information theory, including multiuser data compression, multiple access channels, broadcast channels, and multiterminal networks. Discussion of philosophical and practical implications of the theory. This course, when combined with EE 112 ab, EE/Ma 127 ab, EE 161, and/or EE 167 should prepare the student for research in information theory, coding theory, wireless communications, and/or data compression.

Ma 1abc	Calculus of One and Several Variables and Linear Algebra	Fr	P	P	A

Review of calculus. Complex numbers, Taylor polynomials, infinite series. Comprehensive presentation of linear algebra. Derivatives of vector functions, multiple integrals, line and path integrals, theorems of Green and Stokes. Ma 1 b, c is divided into two tracks: analytic and practical.
Comment: I took the analytical track.

Ma 2ab	Differential Equations, Probability and Statistics	So		A	A

Ordinary differential equations, probability, statistics.

Ma 5abc	Introduction to Abstract Algebra	So	A	A	A

Introduction to groups, rings, fields, and modules. The first term is devoted to groups and includes treatments of semidirect products and Sylow's theorem. The second term discusses rings and modules and includes a proof that principal ideal domains have unique factorization and the classification of finitely generated modules over principal ideal domains. The third term covers field theory and Galois theory, plus some special topics if time permits.

Ma 6a	Introduction to Discrete Mathematics	Fr		P

First term: a survey emphasizing graph theory, algorithms, and applications of algebraic structures. Graphs: paths, trees, circuits, breadth-first and depth-first search, colorings, matchings. Enumeration techniques; formal power series; combinatorial interpretations. Topics from coding and cryptography, including Hamming codes and RSA.

Ma 10	Oral Presentation	Jr		A

In this course, students will receive training and practice in presenting mathematical material before an audience. In particular, students will present material of their own choosing to other members of the class. There will also be elementary lectures from members of the mathematics faculty on topics of their own research interest.

Code	Title	Year	Grade
Ma 11	Mathematical Writing	Jr	A

Students will work with the instructor and a mentor to write and revise a self-contained paper dealing with a topic in mathematics. In the first week, an introduction to some matters of style and format will be given. Some help with typesetting in TeX may be available. Students are encouraged to take advantage of the Hixon Writing Center. The mentor and the topic are selected in consultation with the instructor. It is expected that in most cases the paper will be in the style of a textbook or journal article, at the level of the students peers.

Ma 108abc	Classical Analysis	So	A+	A	A

First term: structure of the real numbers, topology of metric spaces, a rigorous approach to differentiation in $\mathbb{R}^n$. Second term: brief introduction to ordinary differential equations; Lebesgue integration and an introduction to Fourier analysis. Third term: the theory of functions of one complex variable.

Ma 109abc	Introduction to Geometry and Topology	Jr	B-	A-	B

First term: aspects of point set topology, and an introduction to geometric and algebraic methods in topology. Second term: the differential geometry of curves and surfaces in two- and three-dimensional Euclidean space. Third term: an introduction to differentiable manifolds. Transversality, differential forms, and further related topics.

Ma/CS 117a	Computability Theory	Sr	A+

Various approaches to computability theory, e.g., Turing machines, recursive functions, Markov algorithms; proof of their equivalence. Church's thesis. Theory of computable functions and effectively enumerable sets. Decision problems. Undecidable problems: word problems for groups, solvability of Diophantine equations (Hilbert's 10th problem). Relations with mathematical logic and the Gödel incompleteness theorems. Decidable problems, from number theory, algebra, combinatorics, and logic. Complexity of decision procedures. Inherently complex problems of exponential and superexponential difficulty. Feasible (polynomial time) computations. Polynomial deterministic vs. nondeterministic algorithms, NP-complete problems and the P = NP question.

Ma 121abc	Combinatorial Analysis	Jr	A	A	A+

A survey of modern combinatorial mathematics, starting with an introduction to graph theory and extremal problems. Flows in networks with combinatorial applications. Counting, recursion, and generating functions. Theory of partitions. $(0,1)$-matrices. Partially ordered sets. Latin squares, finite geometries, combinatorial designs, and codes. Algebraic graph theory, graph embedding, and coloring.

Code	Title	Year	Grade
	Caltech BS Other Subjects		
Ay 1	The Evolving Universe	Fr	A-

Introduction to modern astronomy that will illustrate the accomplishments, techniques, and scientific methodology of contemporary astronomy. The course will be organized around a set of basic questions, showing how our answers have changed in response to fresh observational discoveries. Topics to be discussed will include telescopes, stars, planets, the search for life elsewhere in the universe, supernovae, pulsars, black holes, galaxies and their active nuclei, and the big bang. There will be a series of laboratory exercises intended to highlight the path from data acquisition to scientific interpretation. Students will also be required to produce a term paper on an astronomical topic of their choice and make a short oral presentation. In addition, a field trip to Palomar Observatory will be organized.

BEM 103	Introduction to Finance	Jr	P

An introduction to corporate finance. Economic theory is used to study asset valuation and financial decision making in business. Topics include financial decision making under certainty, introduction to valuation of risky assets (stocks and bonds), the corporate investment decision, dividend policy, and the corporate financing decision.

BEM 106	Competitive Strategy	Sr	P

This course develops concepts appropriate for formulating strategy in a competitive environment, using a combination of case analysis and lectures. The course covers differentiation strategies, positioning to neutralize incumbency advantages, the product life cycle, organizational design as competitive strategy, signaling, cooperation strategies, pricing and price discrimination as competitive strategy, strategic use of option theory, and the war of attrition.

BEM/Ec 146	Organization Design	Sr	P

An introduction to the analysis, design, and management of organizations with an emphasis on incentives and information. Principles from economics, political science, and game theory will be applied to problems in project and team management, in organizational computing, and in allocating and pricing shared facilities.

Bi 1	Drugs and the Brain	Fr	A

This course introduces nonbiologists to recent advances in biology, biomedical science, and applied biology. The scientific community is beginning to understand the mechanisms of drug addiction, the causes of major neurological diseases, and some medical therapies for these diseases. Because many of these advances involve molecular biology and genetics, the course treats the fundamental aspects of drug actions on the nervous system, from the quantitative, molecular, physical, and chemical viewpoints.

Ch 1ab	General Chemistry	Fr	P	P

Lectures and recitations dealing with the principles of chemistry. First term: electronic structure of atoms, periodic properties, ionic substances, covalent bonding, Lewis representations of molecules and ions, shapes of molecules, Lewis acids and bases, Bronsted acids and bases, hybridization and resonance, bonding in solids. Second term: chemical equilibria, oxidation and reduction, thermodynamics, kinetics, introduction to organic chemistry and the chemistry of life. Graded pass/fail.

Ch 3a	Fundamental Techniques of Experimental Chemistry	Fr	P

Introduces the basic principles and techniques of synthesis and analysis and develops the laboratory skills and precision that are fundamental to experimental chemistry. Enrollment first term will be limited to students who have gained advanced placement into Ch 41 or Ch 21, or by permission of the instructor. Graded pass/fail.

Code	Title	Year	Grade
Ec 11	Introduction to Economics	So	P

An introduction to economic methodology, models, and institutions. Includes both basic microeconomics and an introduction to modern approaches to macroeconomic issues. Students are required to participate in economics experiments.

Ec 132	Auctions	Jr	P

The course covers basic topics in auction theory (private and common value auctions, revenue equivalence, reserve prices, budget constraints, risk aversion, etc.) and discusses more advanced theory such as mechanism design, multi-unit auctions, and interdependent valuations. Experimental studies of auctions will be reviewed where appropriate. The course will also discuss practical considerations that arise when designing auctions to sell licenses in a particular industry.

HPS/PI 133	Philosophy and Neuroscience	Jr	P

This course will examine the impact of recent advances in neuroscience on traditional philosophical problems. Topics may include the nature of free will in light of work on the neural basis of decision making; the nature of consciousness, knowledge, or learning; the mind/brain from the perspective of neural computation; and the neural foundations of cognitive science.

HPS/H 166	Science and Religion	Jr	P

The course develops a framework for understanding the changing relations between science and religion in Western culture since antiquity. Focus will be on the ways in which the conceptual, personal, and social boundaries between the two domains have been reshaped over the centuries. Questions to be addressed include the extent to which a particular religious doctrine was more or less amenable to scientific work in a given period, how scientific activity carved an autonomous domain, and the roles played by scientific activity in the overall process of secularization.

HPS/H 167	Experimenting with History/Historic Experiment	So	P

This course uses a combination of lectures with hands-on laboratory work to bring out the methods, techniques, and knowledge that were involved in building and conducting historical experiments. We will connect our laboratory work with the debates and claims made by the original discovers, asking such questions as how experimental facts have been connected to theories, how anomalies arise and are handled, and what sorts of conditions make historically for good data. Typical experiments might include investigations of refraction, laws of electric force, interference of polarized light, electromagnetic induction, or resonating circuits and electric waves. We will reconstruct instrumentation and experimental apparatus based on a close reading of original sources.

HPS/H 169	History of Mathematics	Sr	P

The course follows the development of mathematical ideas from the dawn of history through the 20th century with a special emphasis on the development of calculus. Half of the time will be devoted to a study and discussion of sections from some of the most important mathematical works ever written from Babylonian cuneiform tablets and Archimedes's method for finding areas and volumes to Euler's derivation of Euler's formulas and Dedekind's construction of the real numbers.

Code	Title	Year	Grade
Hum 3b	Early Modern Europe	Fr	P

Will survey the evolution of European civilization from the 14th century to the early 19th century. The topics covered will depend on the individual instructor, but they will include some of the major changes that transformed western civilization in the early modern period, such as the Renaissance, the Reformation, the rise of sovereign states and the concomitant military revolution, the Scientific Revolution and the Enlightenment, and the French and Industrial revolutions. Readings will include major works from the period, as well as studies by modern historians.

PI 9	Knowledge and Reality	Fr	P

The theme of this course is the scope and limitations of rational belief and knowledge. Students will examine the nature of reality, the nature of the self, the nature of knowledge, and how we learn about the natural world. Students will be introduced to these issues through selections from some of the world's greatest philosophical works, including Descartes's Meditations, Pascal's Pensées, Hume's Enquiry Concerning Human Understanding, Berkeley's Principles of Human Knowledge, and Kant's Prolegomena to any Future Metaphysics. A variety of more contemporary readings will also be assigned.

PE 35a	Beginning Diving	Sr	P

Teaches the fundamentals of springboard diving to include basic approach, and five standard dives. Intermediate class includes instruction in the back somersault, forward somersault, forward somersault full twist, and reverse somersault.

PE 84ac	Table Tennis	Fr	P	P

Introductory course to provide general knowledge of equipment, rules, and basic strokes, including topspin drive, backspin chop, and simple block in both forehand and backhand. Multiball exercise utilizing robot machines and video. Intermediate class covers regulations for international competition and fundamentals of winning table tennis, including footwork drills, smash, serve, and attack.

Ph 1abc	Classical Mechanics and Electromagnetism	Fr	P	P	A-

The first year of a two-year course in introductory classical and modern physics. Topics: Newtonian mechanics in Ph 1 a; electricity and magnetism, and special relativity, in Ph 1 b, c. Emphasis on physical insight and problem solving. Ph 1 b, c is divided into two tracks: the Practical Track emphasizing practical electricity with take-home lab kits, and the Analytic Track, which has no lab component but teaches and uses methods of multivariable calculus.
Comment: I took the analytical track.

Ph 2a	Statistical Physics, Waves, and Quantum Mechanics	So	A-

The second year of a five-term introductory course in classical and modern physics. Topics to be covered include statistical physics and classical waves first term, introductory quantum mechanics second term.

Ph 3	Physics Laboratory	Fr	P

An introduction to experimental technique, commonly used in the physical sciences. A variety of topics are presented, including the Maxwell top, electrical and mechanical resonant systems, and radioactivity. Special emphasis is given to data analysis techniques based on modern statistical methods. The course consists of one three-hour laboratory session a week, conferences with the instructor, prelaboratory preparation, and analysis of experimental results. Graded pass/fail; seniors receive letter grades.

Code	Title	Year	Grade
Ph 12b	Waves, Quantum Physics, and Statistical Mechanics	So	B-

A one-year course primarily for students intending further work in the physics option. Topics include classical waves; wave mechanics, interpretation of the quantum wave-function, one-dimensional bound states, scattering, and tunneling; thermodynamics, introductory kinetic theory, and quantum statistics. May be taken to fulfill the Institute Ph 2 requirement.

PS 12	Introduction to Political Science	So	P

Introduction to the tools and concepts of analytical political science. Subject matter is primarily American political processes and institutions. Topics: spatial models of voting, redistributive voting, games, presidential campaign strategy, Congress, congressional-bureaucratic relations, and coverage of political issues by the mass media.