Beyond Team Teaching: Coordinating Mathematics and Electrical Engineering Curricula

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Introduction.

We present the close coordination between the mathematics and electrical engineering curricula, between mathematics and engineering curricula in general. Team teaching with mathematics and electrical engineering faculty has been used for over ten years here at The Cooper Union. The faculties of both departments meet regularly and discuss broad curricular issues as well as particular topics covered in specific courses. Mathematics and electrical engineering courses are coordinated very closely, while ensuring that mathematics courses accommodate the needs of other engineering majors simultaneously.

With the technological explosion characteristic of the Information Age, electrical engineering is becoming increasingly dependent on advanced mathematical concepts. Mathematics faculties play a vital role in the education of undergraduate electrical engineering students. The role can extend beyond course work by exploiting opportunities to collaborate with electrical engineering faculty on practical projects and applied research.

This coordination impacts the sequencing of undergraduate mathematics courses taken by electrical engineering students, the selection of examples and applications in these courses, the coverage of particular topics, and the offering of elective courses. The net result is that the team teaching concept is applied even when the faculties are not in the same classroom.

Such a close coordination benefits advanced students, who are interested in pursuing graduate studies in engineering or even applied mathematics, as well as students with weaker analytical abilities. Moreover, the faculties of both the departments benefit as well, as they broaden their areas of expertise. As a consequence, this relationship facilitates collaborative efforts on research and design projects. The result is that engineering students benefit not only from technical expertise of mathematics in such projects, but also from witnessing the multidisciplinary collaborative process.

Mathematics courses for electrical engineers.

All engineering students at The Cooper Union take a common set of core courses in mathematics, which are the bedrock of science and engineering. These courses include introductory linear algebra, probability, and calculus through differential equations (including vector calculus and an introduction to partial differential equations). The electrical engineering curriculum requires a math elective relevant to the field beyond these core courses. A large number of electrical engineering students, including a significant number of students in their sophomore year, elect to take an upper level course in linear algebra.

Linear algebra is very useful for required electrical engineering courses including: digital signal processing, control systems, communication theory. It is relevant for a number of elective courses as well, including: digital video, adaptive filters, and wavelets. The course on linear algebra treats vector spaces over arbitrary fields including finite fields. The latter is needed in communication coding. Moreover, infinite dimensional linear spaces (Hilbert space) are considered because of their relevance to signal processing and communications.

A second elective course many electrical engineering students take is discrete mathematics, which helps to support many computer engineering courses, both hardware and software related. Required courses include: digital logic design, computer architecture, programming languages. The electrical engineering curriculum at The Cooper Union will include communication networks as a required course starting in the next academic year. This will serve to increase the relevance of the discrete mathematics course.

A third elective course of particular relevance for electrical engineering is complex variables, which has strong linkages to the study of signals and systems. Specifically, transfer functions (Laplace and z-transforms) studied in courses such as digital signal processing and control systems are, in fact, analytic functions. Several examples include: the Schwarz Reflection Principle, which is the basis for the technique of spectral factorization, used to recover a complete transfer function from only the magnitude information in the frequency domain; Cauchy's Argument Principle, which is the basis of the Nyquist diagram method for stability analysis in control theory; Rouche's Theorem, which is used to study the Schur algorithm and digital lattice filters.

Close linkages exist in the required courses as well. For example, the probability course is essential for signal processing and communications courses. Clearly, discussions of random signals and noise are heavily dependent on probabilistic concepts. However, other subjects studied in electrical engineering, such as information theory, and estimation, detection and decision theory are also based on probability theory.

The differential equations course is also closely tied to the electrical engineering curriculum. The topics of Fourier series and Laplace transforms covered in the course are essential to circuit analysis and signals and systems concepts discussed in the basic electrical engineering courses taken in the sophomore year. Whereas students in other engineering majors take the differential equations course in the spring semester of the sophomore year, electrical engineering students take the course in the fall semester of the sophomore year. Some students with Advanced Placement credit for calculus are even able to take the course in the spring of the freshman year.

Vector calculus, a required course for all engineering student here at The Cooper Union, includes two- and three- dimensional integration, vector and scalar fields, curl and divergence, line and surface integrals, Green, Stokes and divergence theorems. This course is essential for getting a good grasp of the required junior level engineering electromagnetics course.

Coordination of Courses and Syllabi.

The Department of Mathematics accommodates the special needs of the electrical engineering curriculum by offering special sections of certain courses. For example, the differential equations section taken by electrical engineers places a greater emphasis on Laplace transforms and Fourier series.

Electrical engineering faculty prepare special handouts, in consultation with mathematics faculty, for students in engineering courses that summarize key concepts in such subjects as linear algebra, complex analysis, metric spaces and probability. In some cases, these handouts form a basis for the syllabi of the associated math courses. In other cases, these handouts help to inform the mathematics faculty of which topics are of particular importance in electrical engineering, and they influence the development of the syllabi. The mathematics faculty must ensure the integrity and rigor of their courses. For example, it is not realistic to expect the required two-credit sophomore course in probability to discuss stochastic processes, in spite of the importance of the subject in electrical engineering. However, as long as students have familiarity with topics such as joint distributions and expectation (e.g., correlation and covariance), the transition to a discussion of random signals in electrical engineering courses is facilitated.

The selection of textbooks that establish linkages between mathematics and electrical engineering also facilitates such close coordination. For example, one of the texts used in the linear algebra course, by T. Moon and W. Stirling, is entitled Mathemaical Methods and Algorithms for Signal Processing (Prentice-Hall, 2000). One of the textbooks for the required probability course, by H. Stark and J. Woods, is entitled Probability and Random Processes for Signal Processing (Prentice-Hall, 2002).

The close coordination between mathematics and electrical engineering curricula can be extended to other engineering majors and sciences such physics.

Biography.

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