Your Career in the Electrical, Electronics, and Computer Engineering Fields

My engineering education challenged me to reach for the stars. And one day I found myself standing on the moon...

Gene Cernan, Commander, Apollo XVII

In the 1700s, Benjamin Franklin, Alessandro Volta, Luigi Galvani, and other early thinkers sought to understand the nature of an unseen, unnamed energy. Their test materials consisted of such things as kites, frogs' legs, zinc, and salt water. But their findings allowed pioneers in the 18OOs--Ampere, Faraday, Ohm, and Oersted--to discover the electrical properties known as charge, resistance, potential, and current, and the dynamics among them.

Within the next hundred years, Charles Wheatstone and Samuel F. B. Morse had developed electrical communication, resulting in networks of telegraph lines over land and under the sea. The telephone was beginning to transform the concept of communication within cities, while Edison's incandescent light shone in factories, stores, schools, and homes. In 1904 John Ambrose Fleming's diode tube harnessed the electron in a revolutionary way. Electronics was born.

As the heirs to Faraday's and Flemings work, today's electrical, electronics, and computer engineers, technologists, and technicians continue to revolutionize the way we live. We depend on the hundreds of thousands of these individuals who design, produce, operate and maintain a vast array of equipment and services.

Radio, television, telephones, computers, airplanes, space vehicles, automobiles, refrigerators and heaters, office machinery and home appliances, life-saving medical equipment and Martian battles fought with joysticks represent a mere sampling of the now familiar facets of life made possible by engineers, technologists and technicians. In our age of satellite-transmitted television and transcontinental computer networks, the challenges and opportunities in this dedicated profession continue to mushroom. Today's careers, like electricity itself, have enormous potential.

The implementation of ideas through new products, systems, and services is the essence of engineering as a socially responsible profession. The rapid changes in electrical, electronics, and computer technology and the diversity of applications require a broad educational background and a lifelong commitment to learning new and specialized information.

This brochure describes some of the many challenging careers in electrical, electronics, and computer engineering and the educational path necessary to become an engineer, technologist, or technician. Whether you're a student, faculty advisor, or parent, this information will help you make sound decisions about a lifetime pursuit.

Your Career as an Electrical Engineer

Electrical engineering is a profession that uses science, technology, and problem-solving skills to design, construct, and maintain products, services, and information systems. Electrical engineering is the historical name for what is now called electrical, electronics, and computer engineering.

Typically electrical engineers have earned a Bachelor's or Master's degree in engineering in areas that include electronics, electrical engineering, or computer engineering. A junior engi- neer may spend the first year or two on the job learning the company's products and design procedures before choosing a technical specialty. Job responsibilities include specification, design, development, and implementation of products or systems, as well as research to create new ideas. This role provides a number of challenges ranging from problem identification and the selection of appropriate technical solutions, materials, test equipment, and procedures, to the manufacture and production of safe, economical, high-performance products and services.

An electrical engineer may choose to couple the technical aspects of a position with management responsibilities. The technical expertise required for management today is increasing because of the explosion of knowledge in engineering, technology, and science.

A Bachelor of Science degree in engineering with a specialty in electrical engineering may also serve as a starting point for careers in many other diverse fields, ranging from business to law, medicine, and politics, since the problem-solving skills acquired in an electrical engineering program provide an extraordinarily valuable asset. The same skills will equip you to assume leadership roles in your community and in professional circles outside the workplace.

In addition to the primary fields of electrical, electronics, and computer engineering, a Bachelor's degree in electrical engineering serves as an appropriate base for several allied fields. These include, for example, biomedical engineering, com- puter science, and aerospace engineering.

Here are some typical job titles for engineers:

- *Design Engineer*
- *Project Engineer*
- *Engineering Specialist*
- *Chief Engineer*
- *Quality Control Engineer*
- *Software Engineer*
- *Development Engineer*
- *Reliability Engineer*
- *Research Engineer*
- *Systems Design Engineer*
- *Field Engineer*
- *Test Engineer*
- *Sales Engineer*

Your Career as a Computer Scientist

Computer science may be a viable alternative for those who are interested in applying mathematics and science toward the solution of technical problems and who enjoy working with computers but do not desire to pursue a career in engineering. Computer science stresses the more theoretical aspects of both computers and computation.

In many instances, the computer science program is part of the school (college) of engineering or the school of engineering and applied science. In this situation, the first year or two of the computer science program may have considerable commonality with the computer engineering program. After that, the two paths diverge, with the computer science program placing more emphasis on data structures involving additional mathematics, programming languages, and other software concepts.

In other situations, the computer science program may be part of another department of the university and have little if any commonality with the computer engineering program.

Your Career as a Technologist or Technician

Career paths for engineers, technologists, and technicians vary in many ways. Just as the amount and content of education required for these three positions vary, so do professional responsibilities. In general, an engineer's position stresses theory, analysis, and design. A technologist's job incorporates applications of theory, analysis, and design, and a technician is involved with fabricating, operating, testing and troubleshooting, and maintaining existing equipment or systems.

Engineers, technologists, and technicians join together to form a problem-solving and solution-implementing team. A possible scenario could be described this way. An engineer uses theory and design methods to develop products and systems. The design concept is then given to a technologist, who has the responsibility for transforming the concept into a prototype or product. The device is passed to a technician, who is responsible for testing it to confirm the specifications or operation as originally designed. In actual practice, the interactions among members of the team can vary considerably.

Your Education and Employment as a Technologist

Typically, a technologist will have completed a Bachelor of Engineering Technology (BET) or Bachelor of Science in Engineering Technology (BSET) in the field of electrical, electronics, or computer engineering. Employment opportunities range from design operations or sales to project management.

Your Education and Employment as a Technician

Technicians are generally required to complete one to two years of specialized education, usually leading to ail Associate's degree. While technicians are not responsible for designing products or systems, job satisfaction comes from "hands-on" involvement with these products and systems. Technicians typically install, test, and maintain products in the field and are integral to the manufacturing process.

Typical job titles for technologists and technicians include:

Technologist:	**Technician:**
• *Electronics Technologist* • *Biomedical Engineering Technologist* • *Sales Engineering Technologist* • *Customer Service Engineering Technologist* • *Service Engineering Technologist* • *Systems Test Engineering Technologist* • *Product Engineering Technologist* • *Software Engineering Technologist* • *Documentation Engineering Technologist* • *Quality Control Engineering Technologist* • *Applications Engineering Technologist* • *R&D Technologist* • *Engineering Assistant*	• *Service Technician* • *Manufacturing Specialist* • *Field Service Technician* • *Customer Service Representative* • *Test Technician* • *Bench Technician* • *Calibration/Lab Technician*

Additional Factors Affecting Your Career

One way to assess career opportunities is to look at the size and kind of company you want to work for. In a small organization you may have several responsibilities. Restricted capital resources and the small number of employees are often balanced by the speed with which decisions can be made and by the impact of individual ideas or abilities.

In a large corporation, virtually all categories of positions are found, and there is a greater opportunity to specialize in a given area of interest. Large corporations tend to offer a larger number of training programs, greater stability, and more capital and equipment support. Larger companies tend to move more slowly than smaller companies.

Employment opportunities and career paths are affected by changes in the economy and political shifts within society. The engineering profession, like other occupations, is affected by the balance of trade, defense policies, import-export restric- tions, and investment tax policies. The quality and quantity of engineering practiced elsewhere in the world may alter the demand for your own expertise-favorably or unfavorably. As you plan your career, keep in mind that opportunities may change with the times.

An Educational Roadmap to Your Career in Engineering

Because of the diverse activities involved in engineering, technology, and technician

careers, no single approach will guarantee a successful career. Prospective employers look for a wide range of characteristics. In addition to a solid technical background, employers look for such qualities as integrity, ambition, drive, organizational ability, oral and written communication skills, and interpersonal skills. Employers also seek graduates interested in expanding their knowledge and taking on advanced assignments.

Preparing for Your Career While You're Still in High School

Preparation for a career as an engineer, technologist, or technician begins in high school or even earlier. It requires strong grounding in the fundamentals of mathematics and science, with particular emphasis on physics and chemistry. An effective written and oral command of language and a basic understanding of history, culture, and current events are necessary.

You can take one of three educational paths toward a career in the electrical, electronics, or computer engineering fields:

- An appropriate Bachelor of Science or Bachelor of Engineering degree (in electrical, electronics, or computer engineering), leading to employment as an engineer; or
- An appropriate Bachelor of Science in Engineering Technology or Bachelor of Engineering Technology degree (in electrical, electronics, or computer technology), leading to employment as a technologist; or
- An appropriate Associates degree (in electrical, electronics, or computer technology), leading to employment as a technician.

Typical high school requirements for entrance into these programs are shown on the chart below. Keep in mind that each institution has its own admission standards. Therefore, these are general requirements.

A Typical High School Curriculum to Prepare for Your Career

Bachelors Degree Program in Electrical, Electronics, or Computer Engineering or in Computer Science:

- English--4 years
- Mathematics*--4 years
- Science**--3 years
- Social Science--2 years
- Electives
- 15 Units Total

* including trigonometry and precalculus
** including chemistry and physics

Bachelor's Degree Program in Engineering Technology

- English--4 years

- Mathematics--3 years
- Science--2-3 years
- Social Science--2 years
- Electives
- 15 Units Total

Associate's Degree Program in Engineering Technology

- English--4 years
- Mathematics--2-3 years
- Science--2-3 years
- Social Science--2 years
- Electives
- 15 Units Total

As you can see, the typical engineering program requires more mathematics and science in high school than does the Bachelors degree program in technology or the Associate's degree program for technicians. Mathematics, science, and English form an extremely important foundation for an engineering career.

Typical College Curriculum to Prepare for Your Career

Engineering Bachelor's Degree Programs

Electrical and Electronics Engineering

Courses	% time
Math	14
Physics & Chem.	13
Intro. Computing	5
Mechanics & Thermodynamics	5
Electromagnetic Fields	2
Logic Circuits & Lab	3
Computer Architecture & Switching	5
Circuits & Electronics & Labs	13
Energy Conversion	2
Linear Systems	2
Oral/Written Communications	5
Social Science/Humanities	13
Other electives*	18

*Electives may include additional technical courses in Semiconductor Device Construction, Advanced Topics in Computer Languages, Computer Architecture, Computer Construction, Communications, Microwaves, etc., depending on the interests and the size of the faculty. Topics in business and arts and sciences may also be included.

Computer Engineering

Courses	% time

Math	14
Physics or Chem.	13
Intro. Computing	5
Computer Hardware & Microcomputers	7
Software Engineering	7
Lab & Design Work	9
Electrical engineering electives	9
Other technical electives	9
Oral/Written Communications	5
Social Science/Humanities	13
Other electives*	9

Engineering Technology Programs

Bachelor's Degree Program

Courses	% time
Math	13
Physics & Labs	6
Digital Systems & Microcomputers	6
Intro. Programming	2
Advanced Programming	3
Circuits & Electronics & Labs	22
Computer Systems & Applications	5
Linear Systems	2
Communications	3
Control Systems	3
Oral/Written Communication	7
Social Science/Humanities	12
Technical electives	16

Associate's Degree Program

Courses	% time
Math	6-19
Physics & Labs	6
Computer Programming	2
Digital Electronics & Microprocessors/ Microcomputers	3-6
Circuits, Networks, Electronic Devices	12-23
Linear Circuits & Systems	6-19
Machines, Control Systems, Robotics	2-7
Drawing/CAD/Fabrication Skills	2
Oral/Written Communications	5
Social Science/Humanities	5

Engineering courses require a high degree of analytical skill and the ability to handle abstract models of physical phenomena. In general, the more abstract or theoretical the course, the more condensed is the information, and the more broadly it can be applied when accompanied by fundamental concepts and common sense. Learning the theory of engineering allows you to create designs and to build models of systems. It also allows you to analyze the potential failure of systems that have already been constructed.

An electrical engineering program will usually include more mathematics and science than will technology and technician programs. The program may include electives in electronic design, communications, control and signal processing theory, solid state devices, integrated circuit design, radio wave and optical communications systems, and power generation and distribution. Mathematics courses will typically include calculus, differential equations, linear algebra, probability theory, and statistics.

The basic courses of computer engineering are almost identical to those for electrical and electronics engineering. The differences occur toward the end of the college program where the technical concentration is on computer architecture, switching theory, and computer design. You will probably find more electives in numerical methods, database design, operating systems, artificial intelligence, data communications, and voice communications.

Engineering technology programs emphasize both technical and practical proficiency. They are more likely to specialize in a particular discipline starting with the first year. They also include a laboratory experience with almost every technical course, and they usually include courses in computer-aided drafting (CAD), fabrication, software development, data acquisition, and report writing.

An electronics program may emphasize solid-state circuitry and communications, while an electrical program would offer more instruction in electrical machines, control systems, power systems, robotics, and automated manufacturing. Computer technology programs provide students with a stronger background in computer software and hardware, but still include basic circuits and electronics courses.

If you compare courses in engineering with similar courses in engineering technology, you'll find that engineering technology programs tend to be oriented to contemporary devices and systems and current technology. There is less emphasis on the underlying science and more on the here and now.

Work experience can help make educational activities more meaningful, and it often provides insight into the kind of work you will be doing after graduation. A number of universities offer co-op programs, which involve alternating education and work experience. These programs may take longer than the standard four years to complete, but many employers compensate for this with higher starting salaries. Summer jobs or internships in engineering offer alternatives to practical co-op experience and provide some of the same benefits.

Beyond a Bachelor's or Associate's Degree

Because technology is always changing, some applications and methods covered in school may not be useful or current five years later. Your education has only begun with the completion of a formal, full-time educational program. Engineering has been described as a "learning profession," and many engineers spend several hours a week in continuing education, formally or informally.

Additional education in a broad range of subjects other than engineering may be needed in order to meet professional challenges. Such studies might include economics, finance, law, management, and the sciences. Graduate study and other forms of continuing education are activities that engineers must anticipate.

A Bachelor of Science program constitutes the full-time formal education for most

engineering graduates. However, many will continue studying for a Master's degree, and those whose interest is focused on research will pursue a doctoral (Ph.D.) degree.

A Masters degree program is necessary for most advanced design, development and research programs. It generally takes from one to two years of additional full-time effort. A doctoral program typically takes three to five years beyond the B.S. degree and is of primary importance to students who wish to teach or conduct research. Doctoral programs are designed to bring a student to the frontier of knowledge in a specialized discipline and extend that frontier. In a Ph.D. program, you are expected to contribute to advancing the field through a published dissertation.

Sometimes students from Bachelor's degree programs in engineering technology want to go on to graduate programs in engineering or engineering technology. You can transfer directly from a four-year program in engineering or technology into a Master's degree program in technology. However, if you wish to go on to a graduate program in engineering or computer science, you may have to take additional undergraduate courses as required by the individual college or university.

For many technicians, the Associate's degree program fulfills the need for a formal educational experience. However, career advancement and a personal desire for more education frequently draw technicians back to pursue a Bachelor's degree in engineering or engineering technology.

Technical knowledge, management skills, and professional relationships all play a role in determining how far one advances. Additionally, common sense, an ability to relate well with people, and an ability to recognize growing fields will help your career. Some of these skills may be developed by participating in professional societies.

Membership in the Institute of Electrical and Electronics Engineers, Inc.

The Institute of Electrical and Electronics Engineers, Inc. (IEEE) is a transnational professional society with more than 300,000 members in over 130 countries. The world's largest engineering society, its objectives are scientific, educational, and professional.

IEEE strives to advance the theory and practice of electrical, electronics, and computer engineering and computer science. To meet these objectives, the Institute holds more than 4,000 conferences and meetings every year; publishes 23 percent of the world's literature in electrical, electronics, and computer engineering; provides a number of ongoing educational programs; works to advance the professional standing of its members; develops worldwide standards; recognizes excellence in its fields of interest with hundreds of awards and scholarships each year; and promotes the study of the history of electrotechnology

IEEE plays an active role in accrediting engineering and engineering technology programs, as well as computer science programs. It participates in the Accreditation Board for Engineering and Technology (ABET) by providing financial support and volunteers to serve on accreditation committees. Similar support is provided to the Computer Science Accreditation Board (CSAB). Program accreditation ensures that certain educational standards have been met.

IEEE also has a mandate to enhance the quality of life for all people through the

application of technology and to promote a better understanding of the influence of technology on the public welfare. Today, IEEE is the leading source of technical informa- tion in areas ranging from aerospace, computers, and communications to bioengineering, electric power, and consumer electronics.

IEEE and Students

To foster student interest in the profession, IEEE has Student Branches in more than 500 educational institutions throughout the world. Student members have access to all Institute-wide activities and publications, plus a number of special student services. **Potentials** is a quarterly magazine for students that offers guidance in educational and career planning. Student Professional Awareness Conferences are coordinated by individual Branches. An **Employment Guide for Engineers and Scientists** offers salary information and state-by-state listings of prospective employers.

Electrical engineering has been a professional field since 1884. Since that time, technology and areas of expertise have developed to cover a wide range of services. IEEE has expanded with the field and serves members' specialized interests in:

- *Acoustics, Speech and Signal Processing*
- *Aerospace and Electronic Systems*
- *Antennas and Propagation*
- *Broadcast Technology*
- *Circuits and Systems*
- *Communications*
- *Components, Packaging and Manufacturing Technology*
- *Computers*
- *Consumer Electronics*
- *Control Systems*
- *Dielectrics and Electrical Insulation*
- *Education*
- *Electromagnetic Compatibility*
- *Electron Devices*
- *Engineering Management*
- *Engineering in Medicine and Biology*
- *Geoscience and Remote Sensing*
- *Industrial Electronics*
- *Industry Applications*
- *Information Theory*
- *Instrumentation and Measurement*
- *Lasers and Electro-Optics*
- *Magnetics*
- *Microwave Theory and Techniques*
- *Nuclear and Plasma Sciences*
- *Oceanic Engineering*
- *Power Electronics*
- *Power Engineering*
- *Professional Communications*
- *Reliability*
- *Robotics*
- *Social Implications of Technology*
- *Solid State Circuits*
- *Systems, Man and Cybernetics*
- *Ultrasonics, Ferroelectronics, and Frequency Control*
- *Vehicular Technology*

Additional Information on **YOUR CAREER** in Electrical, Electronics, and Computer Engineering May Be Obtained From These Sources:

Schools of Engineering in the United States:

American Society for Engineering Education (ASEE), 1818 N Street, NW, Washington, DC 20036, telephone (202) 331-3500. ASEE publishes two directories annually, one on undergraduate study and another on graduate study and research, in all fields of engineering. They may be purchased from ASEE Publications, same address and phone.

Accreditation Board for Engineering and Technology, (ABET), 111 Market Place, Baltimore, MD 21202, telephone (410) 347-7700. Two publications may be purchased, one listing accredited schools of engineering and the other listing accredited schools of engineering technology, covering all fields of engineering.

Scholarships, Fellowships, Financial Assistance:

Students should talk with the financial aid administrators at the schools of their choice. Special programs may be available for minority students.

Federal Student Financial Aid Information Center, (800) 333-INFO. Information on U.S. Government Assistance to undergraduate and graduate students, all fields of study. A "Student Guide Fact Sheet" may be obtained by writing to Federal Student Aid Programs, P. O. Box 84, Washington, DC 20044.

Information on IEEE related undergraduate and graduate-level scholarships, fellowships, and awards may be obtained from IEEE Student Services, P. O. Box 1331, Piscataway, NJ 08855-1331, telephone (908) 562-5523.

Minorities and Women in Engineering:

National Action Council for Minorities in Engineering (NACME), 3 West 35th Street, New York, NY 10001, telephone 212/279-2626.

Society of Women Engineers (SWE), 120 Wall Street, New York, NY 10005, telephone (212) 509-9577.

Employment Projections for Electrical and Electronics Engineers:

Bureau of Labor Statistics, U.S. Department of Labor, "U.S. Occupational Handbook," available in public libraries. See the section on engineering.

Employers of Electrical and Electronics Engineers:

IEEE's *Employment Guide for Engineers and Scientists, Student Edition*, available in some university libraries. May also be purchased from IEEE; Student Edition, $14.95 members, $19.95 nonmembers); write to Publications Sales Department, IEEE Operations Center, P. 0. Box 1331, Piscataway, N.J. 08855-1331. Includes directory of companies that employ electrical, electronics, and computer engineers.

History of Electrical Engineering:

IEEE Center for the History of Electrical Engineering, Rutgers University, 39 Union

Street, P. O. Box 5062, New Brunswick, NJ 08903-5062, telephone (908) 932- 1066.

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