ENGINEERING

The Department of Physics and Engineering (https://www.bethel.edu/undergrad/academics/physics/) offers multiple ways for students to pursue engineering while obtaining a strong Christian liberal arts and science background. Bethel offers B.S. degrees in Computer Engineering, Electrical Engineering, Mechanical Engineering, and Software Engineering. These programs can be completed entirely at Bethel University. If a student desires an engineering major not offered at Bethel, the B.A./B.S. Dual-Degree Engineering program is available. In this program, students earn both a B.A. from Bethel University and an engineering degree in their desired major from another institution. Students also have the option of combining a minor in engineering with another major.

Engineering Program Educational Objectives

All engineering programs are designed to provide their graduates a solid educational foundation on which they can build successful and sustainable careers in engineering or a related field, using their God-given talents and skills to further His kingdom as their careers develop. In particular, graduates of all of the engineering programs, including Mechanical Engineering, Electrical Engineering, Computer Engineering, and Software Engineering, will be prepared to do the following:

1. To be employed or pursuing an advanced degree in the field of engineering or other related disciplines.
2. To be productive members of interdisciplinary teams.
3. To assume leadership positions in their industry, their continuing education, or in their communities, as their careers develop.
4. To continue their professional development and engage in the life-long learning necessary for a sustainable career.

Student Outcomes

The student outcomes for the engineering programs at Bethel University are:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively, both orally and in writing, with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Advanced Placement: The Department of Physics and Engineering (https://www.bethel.edu/undergrad/academics/physics/) requires a score of 4 or better on an AP exam in order for the exam to be used to fulfill course requirements in the majors it offers. Students with a score of 3 will receive elective credit or receive credit toward General Education requirements. Students should consult the department chair with questions on AP exams and requirements for majors.

Programs in Engineering

B.S. in Computer Engineering (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/engineering/computer_engineering-bs/)
This major equips graduates with the skill set needed to work in the Computer Engineering field. It is a multi-disciplinary program built upon a combination of key courses in mathematics, computer science, physics, and electrical engineering. The work of Computer Engineers is to research, design, develop, and test computer systems and components such as processors, circuit boards, memory devices, networks, and routers. They update existing computer equipment so that it will work with new software, oversee the manufacturing process for computer hardware, and maintain knowledge of computing trends and new technology. They may discover new directions in computer hardware and design non-computer devices that incorporate processors and other computer components that connect to the internet.

B.S. in Electrical Engineering
Electrical Engineers focus on creating electrical and electronic devices ranging in size from tiny microchips to huge power station generators. They work in industries which include consumer electronics, communications, medical devices, automotive, oil and gas, and power production. Electrical engineers integrate electronics, sensors and microprocessors/controllers to create systems that perform specific functions. Design, simulation, manufacturing, and testing are included in the job responsibilities of electrical engineers. Our program is based around our nationally-recognized, experience-oriented approach to teaching engineering, applied physics, and physics; it includes projects and/or lab experiences in most courses. Graduates will have a strong base in physics, math, and computer science, in addition to the distinct advantages of an education rooted in the Christian liberal arts. Hands-on experiences, strong ethics, and good communication skills are emphasized in this program.

B.S. in Mechanical Engineering (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/engineering/mechanical-engineering-bs/)
Mechanical engineering is generally considered the broadest of engineering fields. Mechanical engineers create a wide variety of designs, from internal combustion engines to medical devices, and they oversee the manufacture of these products. Mechanical engineers integrate sensors, controllers, transducers, and machinery. They rely on a good understanding of physics, particularly focusing on the laws of motion and the conservation of mass and energy. Simulation and testing are important components of their work. This program builds on our nationally-recognized, broad-based, experience-oriented approach to teaching engineering and physics with faculty that have doctorates in Electrical, Mechanical, and Aeronautical Engineering, in addition to traditional and applied physicists. Students will have a strong base in physics, math, and computer science, in addition to the distinct advantages of an education rooted in the Christian liberal arts. An emphasis on extensive hands-on experience, strong ethics, and good communication skills characterize the program.

B.S. in Software Engineering (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/computer-science/software-engineering-bs/)
This major prepares students for success in a rapidly growing field. The program is overseen by the Department of Mathematics and Computer Science (https://www.bethel.edu/undergrad/academics/math-cs/) and is taught by a highly-credentialed faculty with exceptional teaching expertise. Graduates working as software engineers will ensure that overall software systems function well within their intended hardware environments. Because graduates will also have completed Bethel's strong General Education program, they can provide clients and/or employers with service that is creative, problem-focused, collegial, and clearly-articulated. A well-developed Christian commitment enables them to work to the highest ethical and performance standards.

B.A./B.S. Dual-Degree Engineering Program (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/engineering/engineering-ba/)
The Dual-Degree Engineering Program is designed to allow Bethel students to complete a major in engineering besides the four fields that Bethel offers. Common examples are Civil, Aeronautical,

Chemical, and Biomedical Engineering. Students earn both a B.A. from Bethel University and an engineering degree from another school of engineering. This combination of degrees has proven to be powerfully attractive to prospective employers who seek well-trained engineers with the communication and leadership skills inherent in a B.A. degree. Students benefit from small introductory class sizes and the Christian emphasis at Bethel while obtaining their engineering degree from any widely respected and recognized school of engineering that offers the engineering field of their choice.

Arrangements to complete the Dual-degree Engineering Program can be made with almost any school of engineering on an individual basis, enabling students to transfer to the school of their choice. Graduation requirements can normally be met in five years or fewer of full-time study. The program is typically arranged as three years at Bethel University and two years at the cooperating university, although students may elect to spend more time at either or both institutions.

Minor in Engineering (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/engineering/engineering-minor/)

Program Requirements for a Dual-Degree in Engineering:

1. All General Education requirements as prescribed in this catalog must be met, except the writing and speaking proficiency courses within the major.
2. Formal application must be made to the chair of the Bethel University Department of Physics and Engineering.
3. Transfer requirements for the cooperating school of engineering must be met.
4. All requirements for an engineering degree at a school of engineering must be completed. The bachelor of arts degree in engineering from Bethel University is not awarded until requirements for degrees from both universities have been met.

Many of Bethel's physics and engineering courses are pre-approved engineering courses by various other schools of engineering. A listing of such courses approved by the University of Minnesota is available from the Department of Physics and Engineering.

Graduate Engineering Program

An increasingly popular option with our students is to major in physics or applied physics and then earn a graduate degree in fields such as Biomedical, Civil, Electrical, Mechanical, Industrial, or Aerospace Engineering.

Normally this means 4 years at Bethel followed by 2 years in graduate school. At the end of 6 years, students have both a B.S. from Bethel and an M.S. from the graduate school of their choice. Many students have also pursued a Ph.D. in engineering. This approach is particularly appealing for those interested in a career that is more involved with engineering research and development.

Typically, our students get full financial support during their graduate work through research or teaching assistantships, tuition waivers, or even fellowships. A few have finished their master's degree in less than 2 years.

Graduate work can be and has been done at a wide range of fine schools.

Programs in Engineering

Majors:

- B.S. in Computer Engineering (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/engineering/computer-engineering-bs/)
- B.S. in Electrical Engineering (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/engineering/electrical-engineering-bs/)

- B.S. in Mechanical Engineering (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/engineering/mechanical-engineering-bs/)
- B.S. in Software Engineering (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/computer-science/software-engineering-bs/)
- B.A. in Engineering (Dual-Degree Program) (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/engineering/engineering-ba/)

Minor:

- Minor in Engineering (https://catalog.bethel.edu/academic-programs/college-of-arts-sciences-and-education/undergraduate-programs/engineering/engineering-minor/)

ENR 160 • Introduction to Engineering 2 Credits
Introduction to engineering fields, engineering practice, engineering work, and the tools and techniques that engineers use. Topics include: engineering design process and methodology, the development of specifications and prototypes, and the ethics and responsibilities of engineers.
Offered: Fall.

ENR 260 • Careers in Engineering and Physics Seminar 1 Credit
Developing careers in high-technology fields such as engineering and physics. Explores the wide variety of specific careers possible through video, lecture, tours, and guest speakers. Develops practical professional skills such as writing resumes and cover letters, accumulating connections and experience, and techniques for interviewing.
Prerequisites: PHY 292/PHY 292D; PHY 296/PHY 297 (may be taken concurrently). Offered: Fall. Special Notes: This course carries cross-credit in physics.

ENR 265 • Computer Aided Design and Engineering 2 Credits
An introduction to computer aided design tools and techniques. Emphasizes the generation of engineering graphics necessary for the engineering design process, such as two-dimensional drawing and three-dimensional solid modeling. Other topics may include simulation modeling and manufacturing considerations.
Offered: Fall. Special Notes: ENR 160 is a recommended prerequisite.

ENR 304 • Engineering Materials and Manufacturing 3 Credits
Introduction to material properties and selection for engineering applications. Topics include: materials and their characteristics; design-based material selection; crystallography; material properties; fracture; fatigue; phase diagrams; engineering alloys; forming, separation, and shaping as manufacturing process for materials; processing of materials according to their properties; surface treatments.
Prerequisites: MAT 125; CHE 113/CHE 113D; PHY 292/PHY 292D with a grade of a C or higher. Offered: Fall, odd # years.

ENR 306 • Digital Logic and Design 3 Credits
Topics may include Boolean algebra, design and optimization of combinational and sequential logic, the use of programmable logic devices such as FPGA, VHDL or Verilog modeling, and an introduction to processors and memory. Extensive lab experience in the simulation, design, construction and testing of digital circuits.
Prerequisites: PHY 302/PHY 303 and MAT 125. Corequisites: Concurrent registration in ENR 307 is required. Offered: Spring, even # years.

ENR 307 • Digital Logic and Design Lab 1 Credit
Laboratory experience accompanying ENR 306.
Corequisites: Concurrent registration in ENR 306 is required. Offered: Spring, even # years.

ENR 308 • Statics and Mechanics of Materials 4 Credits
Force and moment vectors, equilibrium of rigid bodies in two and three dimensions; trusses, friction, centroids, and moments of inertia. Linear elasticity; introduction to stress and strain analysis applied to beams, vessels, pipes, and combined loading; stress and strain; axial, flexural, and torsional deflections for linear elastic materials.
Prerequisites: MAT 223 (may be taken concurrently) and PHY 292/PHY 292D with a grade of a C or higher. Offered: Spring, odd # years.

ENR 316 • Analog Circuitry and Design 3 Credits
Feedback principles and electronic circuit theory and device theory applied to multistage transistor amplifiers. Detailed study of operational amplifiers. Power supply design. Nonlinear circuits. Introduction to filter theory, noise analysis, and low noise design. Circuit design and construction experience emphasized in projects and the laboratory.
Prerequisites: PHY 302/PHY 303; [MAT 222 or MAT 224 (may be taken concurrently)] Corequisites: Concurrent registration in ENR 317 is required. Offered: Fall, odd # years.

ENR 317 • Analog Circuitry & Design Lab 1 Credit
Laboratory experience accompanying ENR 316.
Corequisites: Concurrent registration in ENR 316 is required. Offered: Fall, odd # years.

ENR 318 • Engineering Thermal Science 3 Credits
Fundamental laws of thermodynamics. Energy transfer modes. The properties, equations of state, processes, and cycles for reversible/irreversible thermodynamic systems. Equations for conservation of mass and energy, plus entropy balances. Application of thermodynamic principles to modern engineering systems.
Prerequisites: PHY 296/PHY 297 with a grade of a C or higher and one of the following: MAT 222, MAT 223, or MAT 224. Offered: Spring, even # years.

ENR 321 • Statistical Methods in Engineering 2 Credits
Development of skill in statistical techniques useful to practicing engineers. Included are: random variables and processes; probability distributions and cumulative functions; confidence intervals; hypothesis testing; quality control; random sampling.
Prerequisites: [MAT 222 or MAT 224 (may be taken concurrently)] and MAT 223. Offered: Fall.

ENR 322 • Mathematical Methods in Physics and Engineering 2 Credits
Development of skill in mathematical techniques useful in the solution of physics and engineering problems. Included are Fourier analysis; complex numbers; partial differential equations and their solutions.
Prerequisites: [MAT 222 or MAT 224 (may be taken concurrently)] and MAT 223. Offered: Fall. Special Notes: This course carries cross-credit with physics. ENR 321 is a strongly recommended prerequisite.

ENR 326 • Circuit Analysis & Simulations 4 Credits
Circuit analysis techniques as applied to sinusoidal steady state analysis with power calculations, first and second order transient analysis in both time and Laplace domains, three-phase circuits and magnetically coupled circuits. Additional topics include: frequency response, resonance, filters, Bode plots. Simulation of electrical and electronic circuits are emphasized.
Prerequisites: [(MAT 222 or MAT 224) and MAT 223 (may be taken concurrently)] and PHY 302/PHY 303. Offered: Spring, odd # years.

ENR 336 • Signals and Systems 4 Credits
Continuous and discrete-time signals and systems. Topics include: definitions and properties of signals and systems, convolution, solution of differential and difference equations, Laplace and Z transforms, and Fourier analysis. Emphasis on applications to signal processing, communication and control systems.
Prerequisites: MAT 222 or MAT 224; PHY 302/PHY 303; ENR 352/PHY 352; ENR 353/PHY 353. Offered: Fall, even # years. Special Notes: This course carries cross-credit with physics.

ENR 340 • Mechanics 4 Credits
Particle and rigid body dynamics, conservative and nonconservative forces, central forces, accelerated coordinate systems, and Lagrange's equations of motion.
Prerequisites: PHY 296/PHY 297 with a C grade or higher and MAT 223. Offered: Fall. Special Notes: This course carries cross credit in physics.

ENR 348 • Heat Transfer 3 Credits
Further development of the understanding of thermodynamics, fluid mechanics, mathematics, and physics. The problems in heat transfer and system design are emphasized for systems in which thermal transport processes are important.
Prerequisites: ENR 318 and MAT 222 or MAT 224. Offered: Spring, odd # years.

ENR 352 • Computer Methods in Physics and Engineering 3 Credits
Application of the computer to solve applied problems of interest to physicists and engineers. Computer techniques are developed for numerical methods, simulation models, and data acquisition and control in the laboratory.
Prerequisites: COS 101 or COS 111 and MAT 223 or MAT 224 and PHY 296/PHY 297 with a grade of a C or higher or Consent of instructor. Corequisites: Concurrent registration in ENR 353 is required. Offered: Spring. Special Notes: PHY 302/PHY 303 is a recommended prerequisite. This course carries cross-credit in physics.

ENR 353 • Computer Methods in Physics and Engineering Lab 1 Credit
Laboratory experience accompanying ENR 352.
Corequisites: Concurrent registration in ENR 352 is required. Offered: Spring. Special Notes: This course carries cross-credit in physics.

ENR 356 • Applied Strength of Materials 3 Credits
How the fundamental concepts of stress, strain, and deformation associated with mechanical loading are used in mechanical design. Topics include: axial tensile and compressive effects, torsion, and bending; stress-strain relationships, safety factor, beam deflection methods, buckling, failure prevention theories for ductile and brittle materials, fatigue-life methods and fatigue failure criteria.
Prerequisites: ENR 265; ENR 304 (may be taken concurrently); ENR 308; MAT 223. Corequisites: Concurrent enrollment in ENR 357 is required. Offered: Fall, odd # years.

ENR 357 • Applied Strength of Materials Laboratory 1 Credit
Laboratory experience accompanying ENR 356.
Corequisites: Concurrent registration in ENR 356 is required. Offered: Fall, odd # years.

ENR 358 • Design of Mechanical Components 4 Credits
Emphasizes product design. Developing a mechanical component design problem. Selecting standard mechanical components such as bearings, gears, springs, and fasteners. Analysis and synthesis of motion in machines. Displacement, velocity, and acceleration of mechanisms. Introduction to lubrication theory, flexible mechanical elements, and power transmissions.
Prerequisites: ENR 356/ENR 357. Offered: Spring, even # years. Special Notes: PHY 340 is a recommended prerequisite.

ENR 402 • Mechanical Measurements Lab 3 Credits
A laboratory course focused on careful measurements of physical properties such as temperature, pressure, stress, force, emissivity, and vibration modes. Emphasis placed on experimental methods, statistical estimates of experimental uncertainty, methods of calibration, transducers for mechanical measurement, data acquisition and processing. Appropriate written and oral presentations of measurements.
Prerequisites: ENR 304; MAT 223; PHY 296/PHY 297. Offered: Spring, even # years.

ENR 420 • Software Process 3 Credits
Balancing the various real-world challenges that a software engineer encounters, including ambiguity, conflicting requirements, task-time estimation, team dynamics, requests from customers, product managers or architects.
Prerequisites: COS 277 with a C- or higher. Offered: Spring, odd # years. Special Notes: This course carries cross credit with computer science. ENR 477 is a recommended prerequisite.

ENR 422 • Fluid Mechanics 3 Credits
Laws of statics, kinematics, and dynamics applied to fluid mechanics. Integral and differential conservation laws for mass, momentum, and energy. Dimensional analysis, viscous pipe flow, boundary layers, separated flows, and potential flow.
Prerequisites: MAT 223 and PHY 296/PHY 297 with a grade of a C or higher or Consent of instructor. Corequisites: Concurrent registration in ENR 423 is required. Offered: Fall. Special Notes: This course carries cross-credit in physics.

ENR 423 • Fluid Mechanics Lab 1 Credit
Laboratory experience accompanying ENR 422.
Corequisites: Concurrent registration in ENR 422 is required. Offered: Fall. Special Notes: This course carries cross-credit in physics.

ENR 424 • Electronic Materials and Devices 3 Credits
Theory and application of condensed matter and materials. Physical origin of electrical, optical, mechanical, thermal, and magnetic properties. Emphasis on devices such as pn junction diodes, LEDs, piezoelectrics, and sensors.
Prerequisites: PHY 302/PHY 303 or PHY 312/PHY 313. Corequisites: Concurrent registration in ENR 425 is required. Offered: Fall, even # years. Special Notes: This course carries cross-credit in physics.

ENR 425 • Electronic Materials and Devices Laboratory 1 Credit
Laboratory component of ENR 424. Explores characterization of materials and the design, fabrication, and testing of devices.
Corequisites: Concurrent registration in ENR 424 required. Offered: Fall, even # years. Special Notes: This course carries cross-credit in physics.

ENR 436 • Microprocessors 3 Credits
Advanced principles of microcomputer hardware and software. Topics include: computer organization, instruction sets and addressing modes, assembly language programming, arithmetic and logic operations, input/output, buffers, interrupts and special purpose features such as A/D converters.
Prerequisites: ENR 306/ENR 307. Corequisites: Concurrent registration in ENR 437 is required. Offered: Fall, even # years.

ENR 437 • Microprocessors Lab 1 Credit
Laboratory experience accompanying ENR 436.
Corequisites: Concurrent registration in ENR 436 is required. Offered: Fall, even # years.

ENR 446 • Control Systems 3 Credits
Time and frequency domain representation of feedback control systems. Topics include: stability criteria, root locus methods, frequency response techniques, digital implementation and hardware considerations.
Prerequisites: PHY 302/PHY 303; MAT 222 or MAT 224 (may be taken concurrently). Corequisites: Concurrent registration in ENR 447 is required. Offered: Spring, odd # years.

ENR 447 • Control Systems Lab 1 Credit
Laboratory experience accompanying ENR 446.
Corequisites: Concurrent registration in ENR 446 is required. Offered: Spring, odd # years.

ENR 450 • Topics in Physics and Engineering 3-4 Credits
Topics selected from various fields of engineering and physics for the purpose of illustrating the practical application of physical principles. Emphasis on developing the skills and viewpoints commonly used by engineers and physicists. The field of engineering or physics is announced prior to registration.
Prerequisites: Consent of instructor. Offered: Occasionally. Special Notes: This course may be repeated when a different topic is emphasized. This course carries cross-credit in physics.

ENR 465 • Engineering Design Seminar 1 Credit
Prepares students for engineering practice through a major design experience. Design projects have a major engineering component to them and are intentionally multi-disciplinary in nature. Students work in teams to design a system to meet a given specification that requires the incorporation of relevant engineering standards.
Prerequisites: Senior standing and Major in engineering. Offered: Fall.

ENR 477 • Software Engineering 2 Credits
Formal approach to the design and development of software. Multiple process models discussed and compared. Other topics include design patterns, project management and estimation, team management, formal methods, documentation, system and data description, verification and validation, and process improvement.
Prerequisites: COS 277 with a C- or higher. Offered: Spring, even # years. Special Notes: This course carries cross credit with computer science.

ENR 490 • Engineering Design Project 3 Credits
Prepares students for engineering practice through a major design and prototyping experience. The design produced in ENR 465 is the basis for building a prototype system. The prototype incorporates relevant engineering standards. Final designs and prototypes are documented in a professional manner and presented publicly.
Prerequisites: ENR 465. Offered: Spring.