Electronics and Biomedical Engineering and Prototyping

with Emphasis on Electronics & Biomedical Engineering & Prototyping

Course Level	Grades 10
Length / Credit	Full Year courses / 1.0 High School Credit
Pre / Co-requisites	Algebra I, Computer Science, Intro to Biology
Format	Instruction, laboratory work, engineering design, programming, data analysis, and STEM project development

COURSE DESCRIPTION

This introductory engineering course uses biomedical engineering and STEM competition projects to teach the fundamentals of engineering design. Students survey major engineering disciplines, study the engineering design process, build and test simple electronic systems, develop introductory algorithms, and learn how engineers collect and analyze evidence. Biomedical applications—including sensors, wearables, assistive technologies, veterinary technologies, and physiological monitoring—serve as recurring examples.

Students complete an original engineering project suitable for a high school STEM competition. The course emphasizes safe design, documentation, prototype testing, data analysis, technical writing, and presentation. Human-participant research is introduced at an educational level and must follow the rules of the applicable competition and receive required approval before recruitment or data collection.

LEARNING OBJECTIVES

- Explain the purpose of engineering and distinguish engineering design from scientific investigation.
- Identify major engineering disciplines and representative applications.
- Explain how biomedical engineering integrates biology, medicine, veterinary science, electronics, mechanics, computing, and materials science.
- Apply the engineering design process from problem identification through redesign and communication.
- Define design criteria, constraints, safety requirements, and ethical considerations.
- Use technical sketches, block diagrams, circuit diagrams, and engineering notebooks.
- Use Arduino or Raspberry Pi/Pico platforms to acquire and process sensor data.
- Create simple algorithms using variables, conditionals, loops, calculations, thresholds, and data logging.
- Design appropriate prototype tests and distinguish accuracy, precision, reliability, calibration, and validation.
- Explain basic sampling methods and requirements for ethical human-participant research.
- Collect, organize, graph, and analyze quantitative engineering data.
- Prepare a concise technical report, research poster, and oral presentation for a STEM competition.

- Construct and troubleshoot introductory circuits using breadboards, microcontrollers, sensors, and related components.
- Evaluate whether engineering or a related STEM field is an appropriate area for future college study.

Core Texts, Manuals, and Learning Materials

Resource	Assigned Use
Engineering Text	Moaveni, Saeed. Engineering Fundamentals: An Introduction to Engineering. Cengage. Use selected introductory sections on engineering careers, problem solving, design, units, measurements, and engineering communication. Chapter numbering may vary by edition.
Engineering Design	TeachEngineering, Engineering Design Process curriculum and selected high-school design challenges. Focus: defining problems, criteria and constraints, brainstorming, prototyping, testing, and redesign.
Biomedical Engineering	National Institute of Biomedical Imaging and Bioengineering (NIBIB), Science Education resources. Use selected modules and technology profiles on biomedical imaging, sensors, medical devices, rehabilitation, and bioengineering.
Arduino Manual	Arduino Documentation: Getting Started, Sketches, Digital and Analog I/O, Serial Monitor, I2C/Wire, and selected sensor tutorials.
Raspberry Pi/Pico Manual	Raspberry Pi Documentation: Pico microcontroller boards and MicroPython. Use introductory sections on GPIO, digital/analog input, sensors, serial communication, and data acquisition.
Programming Reference	Monk, Simon. Programming Arduino: Getting Started with Sketches. McGraw Hill. Suggested sections: setup/loop structure, variables, digital and analog I/O, functions, serial communication, and basic libraries.
STEM Competition Rules	Society for Science, current Regeneron ISEF International Rules & Guidelines, especially Rules for All Projects, Engineering and Invention Projects Guide, Human Participants, Form 3 (Risk Assessment), Form 4 (Human Participants), and the Research Plan/Project Addendum.
Research Ethics	The Belmont Report and selected U.S. Office for Human Research Protections (OHRP) introductory materials on informed consent, risk, privacy, and participant protection.
Data Analysis	Spreadsheet software (Excel, Google Sheets, or equivalent) plus instructor materials on descriptive statistics, percent error, correlation, graph selection, and interpretation.

Note: The instructor may substitute equivalent editions or updated official manuals. Current competition rules will replace older versions.

ACADEMIC INTEGRITY

Academic integrity is at the core of education. All academic assignments are essential to the learning experience and to assessing that learning. When students violate the academic integrity policy (i.e., “cheat”), they commit theft that can cause actual harm to themselves and others, including their classmates, instructors, those from whom they steal, and their family and friends. Academic dishonesty confers an unfair advantage over others, which undermines educational equity and fairness and jeopardizes their educational success and future opportunities.

Definitions and Examples of Academic Dishonesty include the following.

a. Cheating is the unauthorized use or attempted use of material, information, notes, study aids, devices, artificial intelligence (AI) systems, or communication during an academic exercise. Examples of cheating include:
    - Copying from another person or from a generative AI system or allowing others to copy work submitted for credit or a grade. This includes uploading work or submitting class assignments or exams to third party platforms and websites beyond those assigned for the class, such as commercial homework aggregators, without the proper authorization of a professor. Any use of generative AI tools must be in line with the usage policy for specific assignments as defined in the course of the syllabus and/or communicated by the course instructor.
    - Using artificial intelligence tools to generate content for assignments or exams, including but not limited to language models or code generators, without written authorization from the instructor.
    - Unauthorized collaboration on assignments or examinations.
    - Taking an examination or completing an assignment for another person or asking or allowing someone else to take an examination or complete an assignment for you, including exams taken on a home computer.
    - Submitting content generated by another person or an AI tool or any other source as solely your own work as your own, including, but not limited to, material obtained in whole or in part from commercial study or homework help websites, or content generated or altered by AI or digital paraphrasing tools without proper citation.
    - Fabricating and/or falsifying data (in whole or in part).
    - Giving assistance to acts of academic misconduct/dishonesty.
    - Altering a response on a previously graded exam or assignment and then attempting to return it for more credit or a higher grade without permission from the instructor.
    - Submitting substantial portions of a paper or assignment to more than one course for credit without permission from each instructor.
    - Unauthorized use during an examination of notes, prepared answers, or any electronic devices such as cell phones, computers, smart watches, or other technologies to copy, retrieve, generate or send information.

b. Plagiarism is the act of presenting ideas, research or writing that is not your own as your own. Examples of plagiarism include:
    - Copying another person’s or an AI tool’s actual words, images, video, or audio without the use of quotation marks and/or proper citations attributing the words to their source.
    - Presenting another person’s ideas or theories in your own words without acknowledging the source.
    - Failing to acknowledge collaborators on homework and laboratory assignments.
    - Internet plagiarism, including submitting downloaded term papers or parts of term papers, paraphrasing or copying information from the internet without citing the source, or “cutting & pasting” from various sources without proper attribution.

- Unauthorized use of AI-generated content; or use of AI-generated content, whether in whole or in part, even when paraphrased, without citing the AI as the source.

c. Obtaining Unfair Advantage is any action taken by a student that gives that student an unfair advantage in his/her academic work over another student, or an action taken by a student through which a student attempts to gain an unfair advantage in his or her academic work over another student. Examples of obtaining unfair advantage include:
    - Stealing, reproducing, circulating or otherwise gaining advance access to examination materials.
    - Depriving other students of access to library materials by stealing, destroying, defacing, or concealing them.
    - Retaining, using, or circulating examination materials clearly indicates that they should be returned at the end of the exam.
    - Intentionally obstructing or interfering with another student's work.

Citations used should be a standard and generally recognized style, such as APA.

Questions concerning Academic Integrity and Citations should directed to instructors or the Head of School.

LATE SUBMISSIONS

Submissions submitted after the announced due date may receive a 10% per day reduction up to 50% of the final grade. Failure to submit course requirements will result in a grade of zero (0) if it is not submitted two weeks after the announced due date.

WORK SCHEDULE

Unit 1 — Engineering Fields and Biomedical Applications (Weeks 1 – 3)

Students are introduced to engineering as applied problem solving. They survey major engineering disciplines and use biomedical engineering to examine how multiple fields work together on a single problem.

Topics

- Engineering vs. scientific investigation
- Mechanical engineering and biomechanics
- Electrical and computer engineering
- Chemical and materials engineering
- Civil and environmental engineering
- Aerospace and systems engineering
- Biomedical and biological engineering
- Medical and veterinary technologies
- Biosensors and physiological monitoring
- Prosthetics and assistive technologies
- Interdisciplinary engineering teams
- Ethics, users, accessibility, and societal impact

Assigned Reading / Learning Materials

- Moaveni, Engineering Fundamentals — introductory sections on the engineering profession and disciplines.
- NIBIB Science Education — selected biomedical technology profiles.
- TeachEngineering — introductory engineering and engineering-career readings.

Assessments

- Engineering disciplines quiz
- Biomedical technology case study
- Interdisciplinary engineering comparison
- Potential STEM problem identification
- Unit 1 exam

Unit 2 — Engineering Design Process and Project Planning (Weeks 4 – 6)

Students learn a structured but iterative engineering design process and apply it to a proposed STEM project. Emphasis is placed on measurable criteria, realistic constraints, documentation, testing plans, and redesign.

Topics

- Identify and define the problem
- Background research and existing solutions
- User needs and stakeholder considerations
- Design criteria and constraints
- Brainstorming and alternative designs
- Decision matrices and design selection
- Technical sketches and block diagrams
- Materials and component selection
- Prototype construction planning
- Testing and performance criteria
- Failure analysis and redesign
- Engineering notebook documentation

Assigned Reading / Learning Materials

- TeachEngineering — Engineering Design Process materials.
- Moaveni — selected sections on problem solving, design, units/measurement, and engineering communication.
- Society for Science — Engineering and Invention Projects Guide and Research Plan/Project Addendum.

Assessments

- Design-process quiz
- Criteria and constraints worksheet
- Decision matrix
- Technical sketch / system block diagram
- STEM project proposal
- Unit 2 exam

Unit 3 — Electronics, Microcontrollers, Sensors, and Algorithms (Weeks 7 – 10)

Students build simple electronic systems and learn how microcontrollers collect and process sensor data. Programming is taught as a practical engineering tool rather than as a full computer-science course.

Topics

- Voltage, current, resistance, and power
- Breadboards, resistors, LEDs, buttons
- Analog vs. digital signals
- Arduino and Raspberry Pi/Pico architecture
- GPIO and analog inputs
- Shields and expansion boards
- Temperature, pressure, force, motion, and light sensors
- Serial, USB, I2C, and SPI concepts
- Variables, loops, conditionals, and functions
- Sampling and data logging
- Calibration and conversion equations

- Threshold and event-detection algorithms

Assigned Reading / Learning Materials

- Arduino Documentation — Getting Started; Sketches; Digital/Analog I/O; Serial Monitor; I2C/Wire.
- Raspberry Pi Documentation — Pico boards and MicroPython introductory sections.
- Monk, Programming Arduino — sections on sketches, variables, I/O, functions, serial communication, and libraries.
- Manufacturer datasheets for sensors used in laboratory activities.

Assessments

- Electronics quiz
- Breadboard circuit lab
- Sensor-interface lab
- Arduino/Pico programming exercises
- Algorithm flowchart
- Mini electronic prototype
- Unit 3 practical exam

Unit 4 — Biomedical Engineering Research and Human Participants (Weeks 11 – 14)

Students learn how biomedical engineering prototypes can be tested responsibly. The unit introduces experimental design, samples and populations, risk, informed consent, privacy, and competition approval requirements.

Topics

- Research question vs. engineering goal
- Independent, dependent, and controlled variables
- Accuracy, precision, reliability, and validity
- Target and accessible populations
- Random and stratified samples
- Convenience and volunteer samples
- Inclusion and exclusion criteria
- Bias and generalizability
- Risk assessment and participant safety
- Consent, parental permission, and minor assent
- Privacy, confidentiality, and data security
- IRB/SRC and pre-approval requirements

Assigned Reading / Learning Materials

- Society for Science — current Human Participants rules; Forms 3 and 4; Sample Informed Consent Statement.
- Society for Science — Rules for All Projects and Overview of Forms and Dates.
- The Belmont Report — sections on Respect for Persons, Beneficence, and Justice.
- OHRP — selected introductory material on informed consent and protection of research participants.

Assessments

- Experimental-design exercise
- Sampling methods quiz
- Human-participant safety quiz
- Mock risk assessment
- Mock research protocol
- Unit 4 exam

Human-Participant Study: Introductory Workflow

1	Define the research question and explain why human participation is necessary.
2	Review current competition/institutional rules and determine required approvals.
3	Identify the population, sample, inclusion/exclusion criteria, and recruitment method.
4	Assess physical, electrical, mechanical, privacy, and psychological risks.
5	Write the protocol: procedures, measurements, duration, data plan, and safety controls.
6	Prepare required forms, consent/assent materials, and risk documentation.
7	Obtain required approval before recruitment or data collection.
8	Recruit voluntarily and complete required consent/assent procedures.
9	Collect data exactly as approved and protect participant information.
10	Analyze aggregate data, identify limitations, and report results accurately.

Human testing of student-designed prototypes may qualify as human-participant research. Institutional Review Board approval must be received before recruitment or data collection. Student prototypes are experimental devices and are not used to diagnose or treat medical conditions.

Unit 5 — Prototype Testing, Data Collection, and Analysis (Weeks 15 – 18)

Students construct or refine a prototype, establish a standardized testing protocol, collect quantitative evidence, and determine whether the design meets its stated performance criteria.

Topics

- Bench testing and simulated inputs
- Calibration and reference measurements
- Verification and introductory validation
- Repeated trials and standardized procedures
- Data tables and version tracking
- Measurement error and uncertainty
- Mean, median, range, and standard deviation
- Percent error and percent difference
- Correlation and trend lines
- Bar, line, and scatter graphs
- Interpreting evidence
- Identifying limitations and redesign priorities

Assigned Reading / Learning Materials

- Moaveni — selected sections on measurement, data presentation, and engineering analysis.
- Instructor spreadsheet guide — descriptive statistics, percent error, graphing, and trend analysis.
- Relevant sensor datasheets and calibration instructions.
- Society for Science — project documentation requirements as applicable.

Assessments

- Prototype design review
- Testing protocol
- Calibration exercise
- Spreadsheet/data-analysis assignment
- Graphing assignment
- Prototype performance report
- Unit 5 project assessment

Unit 6 — Technical Communication and STEM Competition Project (Weeks 19 - 23)

Students complete the engineering cycle by presenting the problem, design, testing, data, limitations, and conclusions in a concise professional format suitable for a high school STEM competition.

Topics

- Engineering abstracts
- Technical reports
- Methods and prototype description
- Results vs. discussion
- Tables and figures
- Schematics and algorithm flowcharts
- Limitations and sources of error
- Conclusions supported by evidence
- Research posters and display boards
- Prototype demonstrations
- Oral presentations
- Responding to judges' technical questions

Assigned Reading / Learning Materials

- Society for Science — current ISEF forms, abstract guidance, and display/safety guidance as applicable.
- Selected examples of strong engineering abstracts, posters, and technical reports.
- Instructor technical-writing guide covering problem, methods, results, discussion, limitations, conclusion, and references.

Assessments

- Final engineering notebook
- Research abstract
- Technical report
- Final data analysis
- STEM poster/display
- Prototype demonstration
- Oral presentation and Q&A
- Unit 6 final project assessment

FINAL STEM ENGINEERING PROJECT

Each student or team develops an original engineering project. Biomedical projects are encouraged but not required. Appropriate areas include wearable sensors, physiological or animal monitoring, assistive devices, biomechanics, environmental health, rehabilitation technologies, smart textiles, data-acquisition systems, and algorithms for interpreting sensor measurements.

- Define a meaningful problem and user need.
- Research existing approaches.
- Establish criteria and constraints.
- Compare alternative solutions.
- Build or model a prototype.
- Integrate electronics/programming when appropriate.
- Develop an objective test plan.
- Collect and analyze quantitative data.
- Document redesign and limitations.
- Prepare a report, poster, and oral presentation.

ASSESSMENT AND GRADING

Category	Weight

Unit coursework and engineering assignments	15%
Laboratory and electronics activities	15%
Quizzes	5%
Unit examinations	20%
Engineering notebook	5%
Prototype development and testing	10%
Research report and data analysis	10%
Final STEM project and presentation	20%

GRADING SCALE

Numerical Grade Range	*Letter Grade*
100.00 – 97.00	A+
96.99 – 94.00	A
93.99 – 90.00	A-
89.99 – 87.00	B+
86.99 – 84.00	B
83.99 – 80.00	B-
79.99 – 77.00	C+
76.99 – 74.00	C
73.99 – 70.00	C-
69.99 – 67.00	D+
66.99 – 64.00	D
63.99 – 60.00	D-
59.99 - 0.00	F

VALUE FOR COLLEGE PREPARATION

The course provides an introductory experience with the open-ended problem solving used in college engineering programs. Students learn to combine mathematics and science with design, electronics, programming, experimentation, statistics, and technical communication. This foundation is useful for students considering engineering, biomedical or biological engineering, computer science, biology, medicine, veterinary medicine, biotechnology, or related STEM fields.