



Industry Certifications – Knowledge and Occupational Skills

Overview

This document outlines the Robotics Education & Competition Foundation's **Pre-Engineering** and **Robotics Industry Certifications**. In preparation for the **Fundamentals of Engineering Module**, we suggest that you prepare curricula or use established curricula that covers the topics in the **Pre-Engineering Modules** selected for your program.

This document is divided into two sections:

- **Section One: Fundamentals of Engineering Skills/Topics:** The first section covers occupational skills and knowledge necessary to understand the topics covered in the Fundamentals of Engineering module. This module is a pre-requisite for all other engineering modules.
- **Section Two: Pre-Engineering Modules:** The second section of this document covers each of the topics for occupational skills and knowledge in each Pre-Engineering module.

See the **Sample Course Sequence** for topics for the Pre-Engineering and/or the Robotics Certification. These work in conjunction with the school's and teacher's expertise, available curricula, and facility to select two of the eight available pre-engineering modules for Pre-Engineering or the three (electronics, programming and mechanical) for the Robotics Certification.

Section One: Fundamentals of Engineering Skills/Topics

Prerequisite: 150 hours in a Pre-Engineering or Robotics Curricula

Exam Length: 90 Minutes

Minimum Passing Grade: 70%

Occupational Skills and Knowledge/Topics

The Fundamentals of Engineering requires knowledge and skills in the following areas:

The History of Engineering

- Early space programs of the US and USSR, the space race, and their technological impacts for today.
- Engineering and technology definitions
- Science definition
- The average work week, salary and wage calculations
- Types of engineering related careers, job outlook, salaries and education required:
 - Mechanical
 - Electrical
 - Chemical
 - Aerospace
 - Civil
 - Computer Science/Programming
 - Technical support for all areas
 - Machining trades: CNC machining, Laser, Rapid Prototyping
 - CAD 2D and 3D applications
 - Robotics

Engineering Design Process

- Ability to apply multiple steps in logical sequence of the design process.
- Ability to understand the proper sequence in various iterations or abbreviations of the engineering design process.

Materials and Processes

- Materials analysis techniques – tensile, hardness, oxidation
- Types of metals, properties and common applications – ferrous, non-ferrous, precious; common alloys – i.e.,: brass, stainless steel
- Types of woods, properties and common applications – hard (Deciduous), soft (Coniferous)
- Types of plastics, properties and common applications – thermosets, thermoplastics, resins
- Types of epoxies, properties and common applications

Safety

General Lab Safety:

- Application of proper eyewear
- Application of proper clothing and footwear
- Application of proper safe practices in a laboratory
- OSHA
- Lab safety colors

Power Tool Safety:

- Band saw – basic band saw operations, application of specific safety procedures
- Bench grinder – basic bench grinder operations, application of specific safety procedures.
- Drill press – basic drill press operations, application of specific safety procedures
- Portable power tools – portable drill operations, application of specific safety procedures

Engineering Drawings

- Orthographic views
- Ability to read electrical schematics, blueprints
- Various common symbols and terminology
 - Ability to find missing views in multi-view drawings by projection, identify the missing views of objects
 - Isometric drawings
 - Develop parts lists with tasks and deadlines
 - Drawing objects to various scales

CAD Systems

- Common lines and symbols used in engineering drawings
- 2D CAD software – Various common programs used in industry
- 3D CAD software – Various common programs used in industry
- Identify orthographic views
- Identify isometric views

Fundamentals of Electrical Engineering

Ohms Law – Amperage, voltage, resistance

Fundamentals of Mechanical Engineering

- Gear ratio calculations
- Isaac Newton's laws
- Kinetic and potential energy
- Thermal systems – heating and cooling

Fundamentals of Robotics systems

- Drive systems
 - 2, 4 and 6 wheel tank or arcade
 - Holonomic
 - Mecanum
 - Omni Swerve
- Microcontrollers
 - Applications
 - Power
 - PWM (Power Width Modulation)
 - Motor Controls: purpose, operation, function
 - Manipulators: arms-wrist-shoulders and elbow-end effectors; degrees of freedom/axis
- Types
 - Collectors
 - Grippers
 - Special applications (limitless) – autonomous control
 - Types of common robotic programs

Fundamentals of Aerospace

- Bernoulli's principle: Lift, thrust, drag
- Early Rocketry
 - Titan II
 - Saturn IV
 - Gemini
 - Mercury
 - Apollo
 - Soyuz
 - V1 and V2
- Common materials used in the aerospace industry

Fundamentals of Civil Engineering

- Methods of transportation
 - Rail
 - Harbors/Ports
 - Roads
 - Bridges
 - Air
 - Rivers/Dams
- Application of bridge efficiency calculations

Fundamentals Computer Science Engineering-Programming

- Binary systems
- Hexadecimal systems
- Basic computer systems
 - RAM, ROM FIFO
 - Storage systems
 - Processor speeds
 - Common programming languages: C and C+, JAVA, HTML

Fundamentals of Chemical Engineering

- Basic lab safety procedures for chemical safety
- Fundamentals of acids and bases
- Periodic chart

Fundamentals of Manufacturing Engineering

- Manufacturing techniques
- Cartesian coordinates calculations
- CAD/CAM systems capabilities
- Three dimensional (3D) printing

Section Two: Pre-Engineering Modules

This is the second section of this document which covers each of the occupational skills and knowledge topics in each “Engineering Module”.

These work in conjunction with the school’s and teacher’s expertise, available curricula, and facility to select two of the eight available engineering areas required for the **Pre-Engineering Certification** or the three engineering areas (electronics, programming and mechanical) required for the **Robotics Certification**.

All eight modules each have the following requirements:

- Prerequisite: Pass the Fundamentals of Engineering module
- Exam Length: 30 Minutes
- Minimum Passing Grade: 70%

Topics for Knowledge and Occupational Skills

Computer Science/Programming Pre-Engineering Module

Requires knowledge and skills in the following areas:

- Common programming languages
 - C and C+
 - JAVA
 - HTML
 - Oracle
 - USB

- Common terminology
 - IP internet protocol
 - Array
 - Floating Point Units (FPU)
 - I/O (input/output)
 - Infinite loop
 - Memory access violation
 - AND gate
 - HTTP, HTTPS
- General understanding of the parts and workings of a computer, including various levels of software from BIOS through applications
 - Input and output devices
 - Central Processing Unit (CPU)
 - RAM
 - ROM
 - Storage devices
- Familiarity with networks and inter-computer communication
 - Routers and their function
 - Internet, intranet
 - Servers and their function
 - Wireless – Radio and wifi
- Binary and hexadecimal representation of numbers
 - Binary representation of 1, 2, 3, 15, etc.
 - Hexadecimal representation of 10, 15, 16, 30, etc.
- Ability to understand simple programs written in C
 - Loops
 - Functions
 - Run time errors
 - Compilation errors
 - Variable types
- Debugging logic errors in a program
- Application problems
 - Find solutions in basic C programming lines
 - Solve binary and hexadecimal representations

Mechanical Pre-Engineering Module

Requires knowledge and skills in the following areas:

- Mechanical systems
 - Rack and pinion
 - Miter gears
 - Worm gears
 - Compound gears
 - Chains
 - Sprockets
 - Pulleys
 - Spur Gears
 - Pneumatics
 - Hydraulics
 - Simple machines: inclined planes, wedges, levers and pulleys
- Applications problems-ability to calculate:
 - Newton's Laws
 - Thermodynamics
 - Acceleration
 - Gear ratios
 - Velocity
 - Engine displacement
 - Speed and torque
 - Compound gear ratios
 - Mechanical advantage

Electrical Pre-Engineering Module

Requires knowledge and skills in the following areas:

- AM and FM radio frequencies
- Mechanical energy
- Motor windings
- Ohms law calculations – ability to calculate:
 - Amperage
 - Resistance Voltage
 - Ohms
- Knowledge of basic computer hardware, i.e. storage devices ,memory, RAM, ROM, FIFO
- Knowledge of and applications for sensors:
 - Potentiometers
 - Ultrasonic
 - Shaft encoders
 - Gyroscopic
 - Accelerometers
 - Optical shaft encoders
 - Line following
 - Light sensing
 - Limit switches

- Applications problems – ability to calculate:
 - Potential energy
 - Kinetic energy
 - Frequency
 - Kilowatt hours costs

Chemical Pre-Engineering Module

Requires knowledge and skills in the following areas:

- Basic Chemical Topics:
 - Chemical reactions and related terms
 - Ideal gas law
 - Kelvin
 - Atmospheres
 - Stoichiometry
 - Solutions
- Periodic Table
- Chemical bonding
- Safety
- Applications
 - Solutions calculations
 - Gas law calculations

Aerospace Pre-Engineering Module

Requires knowledge and skills in the following areas:

- Basic aerodynamic principles: Bernoulli's law-fluid dynamics: flight surfaces, drag, wind resistance, lift and thrust
- Rocket Design
 - Staging
 - Fuels: solid, liquid, nuclear
 - Control: fins, gyroscopes, thrusters (hypergolic and ion electric)
- Types of clouds
- Basic airfoil designs and terminology
- Application problems
 - Newton's drag calculations
 - Wing aspect ratio calculations
 - Horse power to wattage calculations
 - Airspeed and velocity calculations

Civil Pre-Engineering Module

Requires knowledge and skills in the following areas:

- Types of bridges
 - Arch
 - Suspension
 - Girder
 - Truss: Common bridge materials, tension, compression, tensile strength

- Methods of transportation
 - Rail
 - Harbors/Ports
 - Roads
 - Bridges
 - Air
- Rivers, Dams and Canals
- Surveying
- Application problems
 - Boat hull design and displacement applications
 - Surveying
 - Bridge and tower efficiency calculations

Engineering Technology Pre-Engineering Module

Requires knowledge and skills in the following areas:

- Engineering Design Process/Loop
 - 10 step sequence:

1) Identify problem	6) Design
2) Design brief	7) Build
3) Research problem	8) Test
4) Brainstorm problem	9) Redesign
5) Select solution based on research/brainstorming	10) Implement solution(s)
 - Engineering and Technology definitions
- Soft Skills
 - Ability to select appropriate technologies to solve problems
 - Written and oral communications
 - Problem solving techniques-brainstorming-critical thinking
 - Working as a team member
 - How to find and use information
- Manufacturing
 - Common manufacturing practices
 - Computer Numerically Controlled (CNC) applications
 - Three dimensional (3D) printing
- Aerospace
 - Lift
 - Thrust
 - Drag
 - Gravity
- Civil
 - Common types of trusses
 - Bridge and tower efficiency calculations
- Mechanical
 - Gear ratio calculations
 - Pneumatics systems
 - Hydraulic systems

- Programming
 - Binary representations
 - Hexadecimal representations
 - Input and output devices
- Materials and Processes
 - Hardwood and applications
 - Softwood and applications
 - Plywood characteristics and applications
 - Plastics: thermosets applications, thermoplastics applications, composites and applications
 - Ferrous metals
 - Carbon in steel applications
 - Alloys
 - Non-ferrous metals
 - Tensile strength
 - Hardness testing techniques
- Engineering drawings
 - Common lines and representation
 - Dimensioning techniques
 - Orthographic projections
 - Isometric drawings
- Application problems
 - Engineering design process. Synthesize steps in multiple configurations into a proper sequence. Apply proper sequence with multiple models.
 - Select proper tool/equipment for specified tasks. Lab and tool safety situations.
 - Engineering drawings. Identify missing views for orthographic projections.

Manufacturing Technology Pre-Engineering Module

Requires knowledge and skills in the following areas:

- Manufacturing methods
 - Plastic injection molding
 - Sand cast molds
 - Thermoforming
 - 3D printing
 - CNC (Computer Numerically Controlled): water jet, milling, lathe, plasma cutting
- Engineering design
 - CAD systems: 2D and 3D applications.
 - Orthographic views: Number of available views, number of common views
 - Scaling objects
 - Isometric views
- Quality assurance
- Application problems
 - Tensile strength applications
 - Rockwell hardness testing techniques
 - Stress/strains curves: necking, yield strength and ultimate strength