



# 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

- Engineering History: Early space programs of the US and USSR, the space race, and their technological impacts on today; the Industrial Revolution with the introduction of mass production, assembly lines, automation, and the emergence of Engineering Societies (Institute of Mechanical Engineers, Institution of Electrical Engineers).
- 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 shop or 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 of Motion
- 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 Drive
- Micro-controllers
  - 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, Weight (Gravity)
- 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, Moore's Law
  - Common programming languages: Python, C++, JAVA, HTML, Scratch

## Fundamentals of Chemical Engineering

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

## 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 (updated 11\_24\_2021)

Requires knowledge and skills in the following areas:

- Common programming languages, databases and web design
  - C++, JAVA, Python, Scratch
  - HTML
  - SQL, Oracle, DB2
- Common terminology
  - IP - Internet Protocol
  - I/O (input/output)
  - Infinite loop
  - Memory access violation
  - HTTP, HTTPS
- General networking and inter-computer communication
  - Internet, intranet
  - Computer, Server, Cloud
  - Services - ISP, DHCP, DNS
  - Hardware - Switch, Router, Wi-fi
- 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), Floating Point Units, Graphical Processing Unit
  - RAM, ROM
  - Storage devices
- Malware
  - Virus, Worm, Denial of Service, Spam
  - Firewall
- 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 pseudo-code
  - Loops, Queue, Stack
  - Functions
  - Errors - Compile Time, Run Time, Logical, divide by zero, memory allocation error
  - Variable types - integer, character, string, floating point, array
  - Follow program code to determine output or value of given variables
  - Comments in code
- Debugging logic errors in a program
- Application problems
  - Find solutions in basic Pseudo-code programming lines
  - Solve binary and hexadecimal representations
- Robotics
  - Evaluate simple code to determine robot movement and shapes

## **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, weight, lift and thrust
- Rocket Design
  - Staging
  - Fuels: solid, liquid, nuclear
  - Control: fins, gyroscopes, thrusters (hyperbolic and ion electric)
- Types of clouds
- Basic airfoil designs and terminology
- Application problems
  - Newton's drag calculations
  - Wing aspect ratio calculations
  - Horsepower 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
    - 2) Design brief
    - 3) Research problem
    - 4) Brainstorm problem
    - 5) Select solution based on research/brainstorming
    - 6) Design
    - 7) Build
    - 8) Test
    - 9) Redesign
    - 10) Implement solution(s) Soft Skills
  - Engineering and Technology definitions
  - 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