# Robotics and Automation Engineering Technology Standards and Skills

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## Health & Safety Standards

### Standard 1: Safety and Health in a Robotics and Automation Engineering Technology Environment

Students will demonstrate an understanding of safety practices relevant to the Robotics and Automation Engineering Technology environment, including proper tool and equipment operation and maintenance, compliance with OSHA requirements, and promoting a safe, ergonomic workplace.

* Aligned Industry Recognized Credentials: OSHA10 – General Industry, Certified SolidWorks Associate (CSWA)

#### Skills:

1. Identify, describe, and demonstrate the effective use of Safety Data Sheets (SDS) to meet documentation requirements.
2. Locate emergency equipment, first aid kit, and emergency action and response plan, including labels and signage that follow OSHA Hazard Communication Program (HAZCOM).
3. Demonstrate safe dress and use of relevant safety gear, personal protective equipment (PPE), and jobsite ergonomics, e.g., safety equipment, gloves, proper footwear, knee pads, earplugs, eye protection, and breathing apparatus.
4. Demonstrate safe body mechanics, including appropriate lifting techniques and ergonomics aimed at minimizing injury.
5. Ensure that all electrical systems are properly grounded and insulated, with appropriate circuit protection devices in place.
6. Provide training on the risks of electrical shock, arc flash, and other electrical hazards, particularly in environments with high-voltage equipment.
7. Understand OSHA body restraint rules and identify the hazards associated with use of ladders and working at heights.
8. Implement physical barriers, such as safety cages, light curtains, and interlocks to prevent human access to hazardous areas while machines are operating.
9. Design robotic systems according to industry safety standards, e.g., ISO 10218 for industrial robots, ensuring that robots operate within safe speed limits and controlled spaces.
10. Incorporate fail-safe mechanisms to stop the robot safely in case of malfunction or power loss.
11. Establish routine maintenance schedules to inspect and service robotic systems, ensuring that all safety features are functional and that the system operates smoothly.
12. Document all maintenance activities and address any identified issues promptly to avoid potential accidents.
13. Implement strong cybersecurity measures, including firewalls, encryption, and access controls to safeguard both data and operational safety.
14. Implement a tag-out and lock-out shop procedure (LOTO).
15. Understand and apply appropriate fire protection regulations, local permit regulations, and state/federal regulations.

## Technical & Integrated Academic Standards

### Standard 2: Role of Robotics and Automation Engineering Professionals in Society

Students will demonstrate a comprehensive understanding of the historical development of robotics and automation engineering technology, its integration into various industries to enhance efficiency and productivity, and the importance of ensuring compliance with relevant regulatory standards and ethical considerations.

* Aligned Industry Recognized Credentials: CSWA

#### Skills:

1. Explain the role of Robotics and Automation Engineers in advancing technological innovation across various industries, providing examples of recent breakthroughs that have transformed industrial practices.
2. Evaluate the impact of Robotics and Automation Engineers on improving efficiency, productivity, and workplace safety within a specific industry, detailing the technologies or systems they have implemented.
3. Examine how Robotics and Automation Engineers enhance healthcare and quality of life through the development of medical robots and assistive technologies.
4. Demonstrate understanding and adherence to state and federal regulations, industry standards, and safety practices in the installation, maintenance, and operation of robots and automated systems.

### Standard 3: Tools and Instrumentation

Students will select, use, and maintain tools and equipment effectively for applications in the robotics and automation engineering industry.

* Aligned Industry Recognized Credentials: CSWA

#### Skills:

1. Demonstrate the use of threaded and non-threaded fasteners and anchors and install them correctly.
2. Demonstrate operation of power tools and power-actuated tools safely and effectively following industry standards.
3. Demonstrate the use of digital multimeters, oscilloscopes, and data acquisition systems for advanced diagnostics and measurement.
4. Perform accurate electrical measurements using an ammeter, voltmeter, ohmmeter, and volt-ohm-multimeter (VOM).
5. Identify and apply standard methods for making secure electrical connections, including soldering, de-soldering, crimping, and using wire nuts and lugs.
6. Identify and use tools specific to robotics and automation, such as robotic grippers, specialized calibration tools, and diagnostic equipment for automated systems.
7. Select and use basic hand tools and equipment for electronic circuits, such as needle-nose pliers, nut drivers, screwdrivers, wire cutters, wire strippers, and torque drivers.
8. Demonstrate the use of advanced hand tools and equipment for assembling electronic circuits, including Greenlee punches, taps and dies, hand drills, drill presses, and riveters.
9. Utilize both English and International (SI) measurement systems, and accurately calibrate and use electronic devices and gauges for various applications.
10. Define and apply the attributes, units, and systems of measurement commonly used in Mechanical Engineering Technology (MET) fields.
11. Inspect and maintain tools and equipment regularly to ensure safe and efficient operation in compliance with industry standards.
12. Integrate and calibrate tools within robotic systems, including aligning sensors and calibrating robotic arms for precise operation.
13. Apply advanced measurement techniques, including laser measuring tools and automated calibration systems, to enhance accuracy and efficiency.
14. Identify emerging technologies and tools in robotics and automation, such as 3D printing for tool fabrication and automated tool changers.

### Standard 4: Engineering Design Process

Students will demonstrate the ability to apply the engineering design process, from problem identification to the creation and testing of prototypes, while effectively documenting and communicating their solutions.

* Aligned Industry Recognized Credentials: CSWA

#### Skills:

1. Identify and explain the essential components of the engineering design process, including problem definition, research, solution generation, prototyping, testing, and documentation.
2. Define the engineering problem in a concise, written problem statement that captures the scope, constraints, and objectives.
3. Generate and evaluate potential solutions using brainstorming techniques and a structured problem-solving process, ensuring alignment with project goals and feasibility for implementation.
4. Identify and document the critical components and processes of the system to be designed, ensuring clarity in design intent and functionality.
5. Demonstrate building a prototype or model based on the selected solution, ensuring precision and adherence to design specifications.
6. Inspect and test the prototype to verify that it meets all customer specifications, regulatory requirements, and functional expectations using appropriate testing equipment and diagnostic tools.
7. Analyze testing results to identify necessary modifications or improvements and iterate on the design to enhance performance and reliability.
8. Document the entire design process, including problem identification, solution development, prototyping, testing, and final outcomes, in a comprehensive report.

### Standard 5: Technical Communications

Students will develop the ability to effectively communicate technical information through various methods, including written reports, visual diagrams, sketches, and CAD systems, to support design, implementation, and troubleshooting processes.

* Aligned Industry Recognized Credentials: CSWA

#### Skills:

1. Read and interpret technical documents, including technical reports, trade journals, machine manuals, Safety Data Sheets (SDS), and relevant web sources.
2. Generate comprehensive technical reports that clearly communicate findings, design solutions, and recommendations.
3. Identify, read, and interpret electrical schematics and block diagrams.
4. Apply schematic symbols and wiring diagrams according to major international standards, such as IEEE, ISO, and ANSI.
5. Identify and interpret standard flowchart symbols in accordance with major international standards (IEEE, ISO, ANSI).
6. Read and interpret process control flow charts.
7. Use appropriate symbols to develop a process diagram for a given process.
8. Create hand-sketch drawings to communicate technical ideas.
9. Define and describe orthographic projections.
10. Produce fully annotated orthographic projections of a mechanical part.
11. Create a freehand drawing of a mechanical component.
12. Apply various sketching techniques and styles to effectively communicate designs and solutions.
13. Select and utilize the appropriate pictorial style to effectively communicate solutions in the design process.
14. Demonstrate basic use of a CAD system to create 2D-orthographical and pictorial drawings.
15. Read and interpret detailed blueprints and technical processes.
16. Define various geometric shapes and relationships and use appropriate CAD tools to draw basic shapes.
17. Distinguish among and apply various geometric constraints in 3D models, including horizontal, vertical, parallel, perpendicular, tangent, concentric, collinear, coincident, and equal.
18. Apply the Cartesian coordinate system to measure and plot models accurately.

### Standard 6: Fundaments of Mechanical Systems and Processes

Students will design, build, and operate mechanical, hydraulic, and pneumatic systems, applying key mechanical concepts, safety protocols, and schematic interpretations to effectively solve engineering problems.

* Aligned Industry Recognized Credentials: CSWA

#### Skills:

1. Identify and describe the uses of the six simple machines (SM): lever, pulley, inclined plane, screw, wedge, and wheel and axle.
2. Define and explain key terms including, Ideal Mechanical Advantage (IMA), Actual Mechanical Advantage (AMA), power, efficiency, compound machines, work input, and work output.
3. Build and demonstrate a simple machine, explaining its use and operation.
4. Calculate the IMA & AMA for the different SM.
5. Design, build, and operate a Compound Machine.
6. Identify the role that friction plays in SM operation.
7. Apply all safety protocols to the design and building of hydraulic systems.
8. Identify and describe the components of a hydraulic cylinder and their functions.
9. Identify and describe the types and functions of hydraulic pumps, accumulators, actuators, and motors.
10. Identify and explain the schematic symbol for each part of a hydraulic system component.
11. Explain the operation of relief valves, pressure-compensated flow-control valves, check valves, directional control valves, and servo-control valves.
12. Design, build, and operate a hydraulic system, demonstrating its functionality.
13. Apply all safety protocols to the design and build of pneumatic systems.
14. Identify and describe the components used in a pneumatic system, including gases and their functions.
15. Describe the operation of compressors, desiccant dryers, receiver tanks, pressure switches, and pressure regulators.
16. Interpret the schematic symbols for pneumatic system components, including compressors, safety release valves, cylinders, and various types of directional control valves.
17. Design, build, and operate a pneumatic system, demonstrating its functionality.
18. Identify and describe the functions and uses of basic machine operations, including a vertical mill, lathe, and various power tools.
19. Inspect and maintain mechanical systems and components by cleaning, lubricating, and adjusting parts, and record all maintenance procedures.
20. Identify and troubleshoot common problems in mechanical systems, hydraulic and pneumatic systems, and basic machines using appropriate diagnostic tools.
21. Develop and implement corrective actions to restore functionality and efficiency.

### Standard 7: Fundamentals of Electrical Engineering

Demonstrate proficiency in electrical engineering by identifying, analyzing, and designing circuits and systems, applying fundamental principles, and using measurement and simulation tools for effective troubleshooting and optimization.

* Aligned Industry Recognized Credentials: CSWA

#### Skills:

1. Label the parts of an atom and explain their roles in electrical phenomena.
2. Differentiate between insulators and conductors in terms of electron flow.
3. Describe the characteristics and applications of direct current (DC) and alternating current (AC).
4. Explain the differences between analog and digital signals.
5. Identify various switches (NO, NC, SPST, SPDT, DPST, DPDT, Multi-selector) and explain their functions.
6. Identify various types of power resistors and their applications and explain key specifications such as power rating, resistance value, and tolerance.
7. Identify common surface mount resistor packages and their characteristics.
8. Construct and analyze series circuits, applying Ohm’s Law and measuring voltage and current at various points.
9. Investigate Kirchhoff’s Voltage Law in series circuits and Kirchhoff’s Current Law in parallel circuits.
10. Build and analyze series-parallel circuits and calculate power dissipation using Watt’s Law.
11. Identify and explain magnetic principles and theorems.
12. Evaluate the effects of turns, wire diameter, and current on electromagnets.
13. Test and use relays and describe transformer characteristics, including turns ratio, voltage, current, power, and efficiency.
14. Calculate RMS, peak, peak-to-peak, and average values of periodic waveforms.
15. Determine frequency, period, and duty cycle of periodic waveforms.
16. Design, simulate, build, and test half-wave and full-wave rectifiers.
17. Design, simulate, build, and test transistors as switches and explain their bias points in relation to cutoff and saturation.
18. Identify and describe the main parts and functions of DC motors, e.g., field, armature, brushes, and commutators.
19. Explain the operation and performance characteristics of DC motors, e.g., series wound, shunt wound, and compound wound.
20. Describe the main parts and functions of AC motors (rotor, stator), and differentiate between induction and synchronous motors.
21. Explain the concept of three-phase motors.
22. Explain the basics of power generation, three-phase power systems, and power transmission, including high voltage values and local distribution.
23. Explain the use of measurement tools such as oscilloscopes, multimeters, and signal generators for circuit analysis and testing.
24. Examine advanced circuit analysis techniques such as mesh and nodal analysis.
25. Explain basic analog filter circuits (low-pass, high-pass, band-pass, band-stop) and their applications.
26. Apply troubleshooting methodologies for identifying and fixing common problems in electrical circuits.
27. Examine Programmable Logic Devices (PLDs) such as FPGAs and CPLDs and their role in digital circuit design.
28. Perform conversions between decimal, binary, and hexadecimal number systems.

### Standard 8: Fundamentals of Sensor Technologies

Students will be able to apply various sensor technologies by describing their measurement characteristics, comparing features and costs, and evaluating the advantages and limitations of both traditional and modern sensors in control systems and robotics applications.

* Aligned Industry Recognized Credentials: CSWA

#### Skills:

1. Describe the operation and use of a potentiometer to measure mechanical movement in a control system, focusing on measurement characteristics and cost considerations.
2. Evaluate advanced digital sensors, such as magnetic encoders and capacitive sensors, discussing their features, costs, and why modern alternatives may be preferred in contemporary applications.
3. Explain the operation and applications of absolute and incremental optical rotary encoders, emphasizing their measurement characteristics and cost-effectiveness.
4. Discuss the characteristics and operation of velocity sensors, analyzing their applications in various control systems.
5. Evaluate the operation and applications of optical tachometers in control systems.
6. Assess the advantages of modern sensor technologies, including optical encoders, digital tachometers, and sensor less control techniques.
7. Explain the characteristics and operation of various proximity sensors, including mechanical limit switches and modern alternatives, and compare their functionality and applications in contemporary control systems.
8. Describe the operation and applications of ultrasonic proximity sensors in control systems with an emphasis on their measurement characteristics.
9. Explain the operation and use of inductive and capacitive proximity sensors.
10. Describe the operation and applications of hall-effect proximity sensors.
11. Explain the characteristics and operation of load and force sensors.
12. Discuss the operation and use of strain gauges in control systems.
13. Compare the features of traditional strain gauges and pressure sensors with MEMS-based alternatives, including their advantages, limitations, and applications in modern control systems.
14. Explain the characteristics and operation of pressure sensors, discussing their use in control systems and their cost-effectiveness.
15. Compare the characteristics and operation of RTDs, thermocouples, and thermistors with integrated digital temperature sensors, e.g., I2C and SPI-based sensors, highlighting the benefits of digital sensors for interfacing and integration with modern microcontrollers.
16. Evaluate the operation and applications of RTDs, thermistors, and thermocouples in temperature control systems.
17. Explain the operation and application of an integrated-circuit temperature sensor and evaluate its advantages and limitations in temperature control systems.
18. Discuss the setup and troubleshooting of smart sensors and industrial transmitters.

### Standard 9: Fundamentals of Programming and Programmable Logic Controllers

Students will design, develop, and implement PLC systems by understanding PLC components, hardware, and programming fundamentals, creating and interpreting wiring diagrams, and applying programming techniques and HMI integration for effective automation control.

* Aligned Industry Recognized Credentials: CSWA

#### Skills:

1. Identify and explain the basic building blocks and major components of PLCs, including fixed and modular types, and discuss their advantages.
2. Describe the advantages of PLCs in automation, including their modes of operation and the criteria used to categorize them (functionality, number of inputs/outputs, cost, and size).
3. Identify and explain PLC programming devices, and describe the major hardware components, including the CPU, power supply, memory types, and field device connections.
4. Describe the specifications and operation of PLC I/O modules (Discrete, Analog, Specialty) and explain I/O addressing formats.
5. Identify and describe the various terminal programming devices used for PLCs and explain the role and applications of Human Machine Interfaces (HMIs).
6. Explain the role of electromagnetic relays and NO/NC contacts in PLC programming and wiring diagrams.
7. Develop and interpret PLC programming and wiring diagrams for components like motor starters, contactors, manually operated switches, and sensors, and create diagrams from electromagnetic relay logic and narrative descriptions.
8. Create PLC programming and wiring diagrams from electromagnetic relay logic and narrative descriptions.
9. Develop PLC programs using functions such as delay and retentive timers, counters, program control instructions (Master Control Reset, Jump, and Subroutines), data manipulation, data comparison, basic math functions, sequencer and shift register instructions, and programming blocks for analog inputs/outputs and PID control.
10. Design and implement HMI programs to monitor PLC operations, adjust timer and counter values, and manage I/O devices.
11. Develop and implement advanced PLC programs using function blocks and structured text and apply data logging techniques to enhance system diagnostics and performance analysis.
12. Design and configure PLC systems to integrate with SCADA systems and IoT devices, enabling seamless data exchange and control across multiple automation platforms.

### Standard 10: Robotics Technology

Students will be able to design, simulate, build, and program industrial robots and robotic systems, demonstrating a comprehensive understanding of robot components, control systems, programming techniques, and application scenarios.

* Aligned Industry Recognized Credentials: CSWA

#### Skills:

1. Explain the fundamental components and specifications of industrial robots, including arm geometry, degrees of freedom, position and orientation axes, work envelope, and tool center point, and describe how these factors affect robot performance.
2. Identify and explain the classification of industrial robots by arm geometry and describe their impact on robot performance, including specific applications for each type.
3. Define and provide examples of key robot specifications, such as payload, repeatability, memory capacity, and environmental requirements, and apply this knowledge to select appropriate robots for various tasks.
4. Identify and describe the various actuators and drive mechanisms used by industrial robotic arms and explain their roles in robot movement and functionality.
5. Identify and explain the various controllers and power sources used by industrial robots, including their functions and how they contribute to robot operation.
6. Describe the various types of end-of-arm tooling used by industrial robots and explain how they are selected and applied for different tasks.
7. Identify and describe the teaching and programming devices used for accurate robot programming and explain their importance in setting up and modifying robot operations.
8. Describe the different data storage devices used by industrial robots and explain their role in storing programs, settings, and operational data.
9. Explain the differences between open-loop and closed-loop control systems used in industrial robots, including their applications and limitations.
10. Identify and classify the different types of industrial robots based on their structural design, functionality, and application, including Cartesian, SCARA, and articulated robots.
11. Describe the various arm geometries employed in industrial robots and their specific applications, including the advantages and limitations of each geometry.
12. Examine the various power sources used by industrial robots and discuss their advantages and limitations, including electric, pneumatic, and hydraulic systems.
13. Explain the different path control techniques used by industrial robots, such as point-to-point control, continuous path control, and trajectory control.
14. Describe the operation and applications of simple contact sensors used in industrial robot work cells, including their role in detecting physical contact and enhancing safety.
15. Describe and explain the operation and applications of simple noncontact sensors in industrial robots such as infrared, ultrasonic, and laser sensors.
16. Describe the operation and use of process control sensors in industrial robot work cells, explaining how these sensors monitor and control process parameters such as temperature, pressure, and flow rate to ensure process stability and efficiency.
17. **Explain end-of-arm tooling for industrial robots by defining key terms, describing their functions, and identifying various types of tooling, including grippers, sensors, and effectors.**
18. **Identify and describe the power sources used for end-of-arm tooling and their applications in robotic systems.**
19. **Identify and explain the functions of different types of grippers, including standard, servo, non-servo, vacuum, and magnetic, and discuss their specific uses in various industrial tasks.**
20. Identify the complexities involved in programming industrial robot work cells and describe the challenges faced, including issues related to system integration and programming accuracy.
21. Identify and explain the functions of the robot controller, including its role in programming and controlling the robot.
22. Explain online programming, including the methods used and how it is accomplished, highlighting its advantages and applications.
23. Explain offline programming, including the methods used and how it is accomplished, and discuss its benefits and typical use cases.
24. Demonstrate building a mobile robot by assembling the components and ensuring proper integration of mechanical and electronic parts.
25. Develop and upload code to operate the mobile robot, including implementing functions for movement and control.
26. Demonstrate operating the robot using a remote-control unit to manually navigate and perform tasks.
27. Program and test the robot’s autonomous capabilities, including forward and backward movement, turning, and adjusting power levels.
28. Integrate sensors to detect external conditions and adjust the robot’s operation accordingly for enhanced functionality.
29. Implement loops and conditional statements in the robot’s programming to enable decision-making and responsive behavior.

### Standard 11: Automation Systems Design and Optimization

Students will apply their knowledge and skills to design, implement, and optimize automation processes in motor control systems, robotic operations, and manufacturing routines.

* Aligned Industry Recognized Credentials: CSWA

#### Skills

1. Explain the fundamental components and specifications of automated systems, including sensors, actuators, and control mechanisms.
2. Examine the role of robotics in automation, highlighting the impact of different types of robots and their applications across various industrial processes.
3. Assemble and build a motor control application, ensuring the proper integration of control systems and mechanical components.
4. Develop and construct a pneumatic vise application, incorporating automated control mechanisms to ensure precise operation.
5. Design and implement a clamp and drill routine, focusing on automation to achieve accuracy and efficiency.
6. Construct an injection molding machine with automated controls to ensure consistent product quality.
7. Design and build a robot gripper and control routine, including the integration of sensors and actuators for effective gripping and manipulation.
8. Develop a palletizing routine, incorporating automation for efficient stacking and arrangement of products.
9. Design and implement a batch process routine, focusing on automation to achieve consistent batch production.
10. Create a sorting process automation system, integrating sensors and actuators to enhance material handling and sorting efficiency.
11. Assemble and program a mobile robot application, ensuring proper integration of mechanical, electronic, and software components.
12. Develop and set up a robotic workstation, integrating multiple robotic systems and automation components to create a functional workspace.
13. Integrate various components and systems within an automated environment, ensuring seamless operation and efficiency.
14. Apply diagnostic tools and techniques to troubleshoot sensor malfunctions, actuator failures, and control system errors within an automated environment.
15. Optimize the performance of automated systems by analyzing and adjusting parameters for improved functionality and output.
16. Test and evaluate the performance of built systems and robots, identifying areas for improvement to ensure they meet design specifications and operational standards.
17. Analyze the energy consumption of automated systems, identifying opportunities to improve energy efficiency through system optimization and the integration of energy-saving technologies.

## Employability Standards

### Standard 12: Employability Skills

Students will understand and demonstrate the roles of professional communication, critical thinking, problem solving, professionalism, teamwork, and collaboration within the context of the robotics and automation engineering industry.

#### Skills:

1. Demonstrate effective communication and positive people skills to provide exceptional customer service across various platforms, including face-to-face interactions, telephone conversations, written, and electronic correspondence.
2. Demonstrate the ability to analyze complex problems and develop effective solutions.
3. Demonstrate active listening skills by giving full attention to others, taking the time to understand their points, and asking appropriate questions to meet job expectations and production methods.
4. Demonstrate working effectively in teams to achieve common goals, sharing technical information, coordinating with other professionals such as engineers, contractors, and project managers to support design and implementation of robotics and automation systems.

## Entrepreneurship Standards

### Standard 13: Entrepreneurship

Students will be able to describe opportunities for entrepreneurship and be able to evaluate the value proposition of business ownership in the robotics and automation engineering industry.

#### Skills:

1. Evaluate the licensing, regulatory, and tax implications of self-employment and business ownership in the robotics and automation engineering industry compared to W-2 employment.
2. Understand current job trends, skill requirements, and potential growth areas within the modern robotics and automation engineering, including roles in systems design, maintenance and repair, and communications infrastructure.
3. Develop and implement a marketing strategy that targets specific segments within the robotics and automation engineering markets, incorporating branding, sales techniques, and opportunities for innovation and product development throughout the lifecycle from concept to market.

## Digital Literacy Standards

### Standard 14: Digital Literacy

Students will demonstrate proficiency in using common software and information technology tools in the robotics and automation engineering industry.

#### Skills:

1. Demonstrate proficiency in using Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software to design robotic components and simulate automation processes.
2. Understand the importance of cybersecurity in protecting automated systems from digital threats, including securing networks, devices, and data.
3. Demonstrate skills in designing and interacting with HMIs permitting operators to monitor, control, and interact with automated systems effectively.
4. Understand how to integrate robotics and automation with cloud computing and the Internet of Things (IoT) to enable remote monitoring, control, and data analysis.
5. Demonstrate knowledge of artificial intelligence (AI) and machine learning concepts to enhance the capabilities of robotic systems, including adaptive learning and autonomous decision-making.
6. Create, store, and share digital documentation, including project reports, equipment logs, compliance records, and budget tracking to ensure comprehensive and organized project management.  
   Learn and apply new digital tools, platforms, and technologies as they emerge in the robotics and automation engineering industry.