Manufacturing

Career Field Technical Content Standards

Ohio Department of Education & Workforce

Foreword

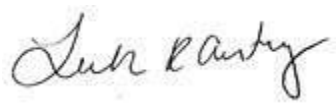
The Career Field Technical Content Standards serve as the curricular framework for Ohio's career-technical education pathway programs as outlined in Ohio Administrative Code 3301-61- 03 (Criteria for Secondary Workforce Development Programs).

Career Field Technical Content Standards outline the knowledge and skills needed for success in careers across multiple pathways. Validated by Ohio business and industry representatives in conjunction with Ohio educators, these standards form the basis for developing educational programming in Ohio secondary schools. The standards also serve as the framework for developing strong career pathways that connect secondary education with postsecondary education systems and the workplace.

This version of Career Field Technical Content Standards is intended to support the ongoing evolution of career technical education pathway programs. The standards tend to be somewhat broader than previous versions and are not repeated for individual pathways or occupational areas. The broader and non-duplicated statements are intended to capture the knowledge and skills that can be applied across any number of occupations in a pathway rather than focusing on the requirement of a single occupation. After all, the intent of a pathway program is to prepare a student for a range of educational and career opportunities following high school.

Pathway programs prepare students to combine broad knowledge, insight and understanding of business processes, academic attainment, and workplace readiness with depth of knowledge and expertise in a technical area. Knowing that many careers will require some level of postsecondary education, the content standards also delineate the knowledge and skills necessary to seamlessly transition to postsecondary educational programs.

This document seeks to provide the basis for educational programming that will provide the employee with fundamental skill sets that employers demand. This ensures that Ohio's workforce of tomorrow is competitive in a global environment. An environment that requires knowledge and skills can be applied in a broader context, aimed at innovation to support new products and services in an ever-changing economy.



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Department of Education & Workforce

Acknowledgements

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Philosophy and Principles for Implementation

Ohio Career Field Initiative

The overarching framework for Ohio career-technical education is outlined in the Ohio Revised Code and subsequent administrative rules, which specify career-technical programming based on 16 career fields. These 16 fields provide the framework for an Ohio career field initiative that seeks to foster the educational shift necessary to respond to the needs of a rapidly changing global environment.

A career field is a "group of occupations and broad industries based on common characteristics". Career fields are the basis for developing both broad and specialized technical content standards that serve as a framework for curriculum, instruction, assessment, and program design, addressing the needs of an entire industry and business sector. Ohio's 16 career fields align with national efforts to broaden career-technical education, integrate career-technical with academic study and reflect the workforce needs of today and tomorrow. For today's students to be adequately prepared for tomorrow's workforce, they must have an education that:

- ***Incorporates a broad, long-term conception of work in combination with the depth of specialization skills;***
    - Employees need a comprehensive understanding beyond a single occupational area. Career- technical programming needs to be provided in a larger context, so students can generalize learning, make connections between education and work and adapt to changes in their careers. Workplace knowledge and skills are needed to prepare employees for collaborating and problem solving while contributing to the broader business process.

- ***Emphasizes the acquisition of strong academic knowledge and skills; and***
    - Academic skills provide the foundation for career success. The integration of academic content standards with career field technical content standards helps to contextualize learning for students, making English language arts, mathematics, social studies and science relevant to students as a means to an important end—success at work and in life.

- ***Facilitates high-school-to-postsecondary transitions.***
    - A lifetime of change means a lifetime of learning, including postsecondary education. Students need knowledge and skills for success in a variety of postsecondary options, including apprenticeships, industry credentialing through adult education, two- and four-year college degree programs and graduate school.

Career Pathways

A key component of the Ohio Career Field Initiative is a career pathway, which is a coherent, articulated sequence of rigorous academic and career-technical coursework commencing in the ninth grade and leading to an associate degree, baccalaureate degree and beyond–an industry- recognized certificate and/or licensure. Pathways facilitate a seamless transition from high school to postsecondary education (including apprenticeships, adult education, two- and four- year colleges and graduate school) and from postsecondary education to the workplace. The career pathway is developed, implemented, and maintained in partnership among secondary and postsecondary education, business, and employers. Career pathways are available to all students, including adult learners, and lead to rewarding careers.

To effectively facilitate the transition from secondary to postsecondary education and a career, high school career pathways should encompass:

- Challenging technical coursework in a chosen career field based on career field technical content standards;
- Rigorous academics that meet Ohio's academic content standards and grade-level expectations;
- Electives that relate to career objectives;
- Instructional enhancements such as experiential and authentic learning opportunities (e.g., work-based learning, mentorships, internships) and career-technical student organization participation;
- Opportunities (when appropriate) for program and student certification and licensure;
- Preparation for transition to further study that includes college readiness and opportunities to earn college credit while in high school;
- Preparation for transition to employment with advancement opportunities;
- Performance targets that include high school academic and technical testing/exit and postsecondary entry/placement requirements;
- Various sector(s) within an industry or encompass a function that crosses industry sectors;
- The scope of opportunities in the related industry and available college programs;
- Opportunities to prepare for a range of careers, including
    - multiple employment opportunities after high school and
    - opportunities for students to enter and succeed in postsecondary and continuing education programs;
- Transferable skills required for employment in the range of occupations aligned to the pathway; and
- Opportunities to learn skills across the pathway as well as in specialized areas.

Structure and Format

The Career Field Technical Content Standards document is composed of a series of strands comprised of outcomes that each contain a set of competencies.

- A strand is a large content area under which multiple outcomes are organized, regardless of the pathway. It includes a title and a concise description with statements that capture multiple, broad areas of learner knowledge and skills expected across all outcomes in the strand. There are approximately six strands of content per career field. Strand 1, Business Operations/21st Century Skills (employability skills, leadership and communications, business ethics and law, knowledge management and information technology, global environment, business literacy, entrepreneurship/entrepreneurs, operations management, financial management, sales and marketing and principles of business economics), is the same for all career-technical education career fields.
- An outcome is an overarching statement that summarizes the knowledge and skills described in a set of individual competencies to be learned by the end of the 12th grade. There are usually 5–15 outcomes within a strand, depending on the breadth of content to be addressed.
- Competency is a specific statement of essential knowledge or skill to be learned in the pathway program. There are usually 5–12 competencies under an outcome.

Each set of outcomes and competencies is included in one or more pathways in the career field. Outcomes and competencies form the basis for developing secondary courses, programs, instruction and assessment, facilitating transition from one educational level to the next and to the workplace. This supports career readiness and long-term career success by:

- Providing the basis for effective collaboration, teamwork and communication across pathways;
- Laying the groundwork for successful transfer of knowledge and skills across pathways,thereby facilitating horizontal and vertical career success; and
- Equipping students and workers with the skills needed to transition to new and emerging careers throughout a working lifetime.

All outcomes and competencies in the Career Field Technical Content Standards have been verified as essential by business and labor representatives within the pathway or pathways specified. These essential outcomes and competencies specify industry-based knowledge or hands-on skills that CTE students need by the end of the 12th grade to be successful in their selected career pathway and on-going learning (such as college, apprenticeships and military opportunities).

Development of Career Field Technical Content Standards

The process for the development of the Manufacturing Career Field Technical Content Standards began in January of 2024 and culminated in August of 2025. Over the course of 2024-2025, numerous business and industry representatives as well as secondary and postsecondary educators from across the state of Ohio took part in the formal development process. The following summarizes the various stages of the development process.

Business and Industry Panels

Beginning in June 2024, the Engineering & Manufacturing panels brought together key business and industry representatives from across the state to advise the Ohio Department of Education and Workforce on trends impacting the Manufacturing industries. The participants were asked to share their perceptions on changes in the workplace, employment trends, changes in technical skill requirements, needed workplace readiness skills and available industry-recognized standards and credentials. This feedback was used to develop and streamline the standards document into what is most demanded by the labor market.

In November 2024, a diverse group of Ohio business and industry representatives participated in panels to validate and rate the importance of the work-related competencies in the draft standards document. Drawn from various sectors and regions of the state, the panels identified what employees should know and be able to do in the Engineering and Manufacturing pathways. Secondary and post-secondary education representatives participated on the panels to gain an understanding of the standards development process as well as to provide their perspective to the business representatives, when needed.

Post-Secondary Alignment

The goal of the Secondary Career-Technical Alignment Initiative (SCTAI) was to develop new statewide Career-Technical Assurance Guides (CTAGs) for secondary career-technical institutions using the combined process of the Ohio Board of Regents' CTAG development process with the Ohio Department of Education's Career Field Technical Content Standards development process. The result of this collaboration was a tighter alignment between secondary career-technical and postsecondary content and the development of pathways that encourage college-going and increase statewide postsecondary options for career technical students.

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Engineering and Manufacturing Technical Content Standards 1-10

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.1 Employability Skills: Develop career awareness and employability skills (e.g., face-to-face, online) needed for gaining and maintaining employment in diverse business settings.

Competencies:

1.1.1. Identify the knowledge, skills and abilities necessary to succeed in careers.
1.1.2. Identify the scope of career opportunities and the requirements for education, training, certification, licensure and experience.
1.1.3. Develop a career plan that reflects career interests, pathways and secondary and post-secondary options.
1.1.4. Describe the role and function of professional organizations, industry associations and organized labor and use networking techniques to develop and maintain professional relationships.
1.1.5. Develop strategies for self-promotion in the hiring process (e.g., filling out job applications, resumé writing, interviewing skills, portfolio development).
1.1.6. Explain the importance of work ethic, accountability and responsibility and demonstrate associated behaviors in fulfilling personal, community, and workplace roles.
1.1.7. Apply problem-solving and critical-thinking skills to work-related issues when making decisions and formulating solutions.
1.1.8. Identify the correlation between emotions, behavior and appearance and manage those to establish and maintain professionalism.
1.1.9. Give and receive constructive feedback to improve work habits.
1.1.10. Adapt personal coping skills to adjust to taxing workplace demands.
1.1.11. Recognize different cultural beliefs and practices in the workplace and demonstrate respect for them.
1.1.12. Identify healthy lifestyles that reduce the risk of chronic disease, unsafe habits, and abusive behavior.

Strand 1. Business Operations/21st Century Skills

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Outcome 1.2: Leadership and Communications: Process, maintain, evaluate and disseminate information in a business. Develop leadership and team building to promote collaboration.

Competencies:

1.2.1. Extract relevant, valid information from materials and cite sources of information.
1.2.2. Deliver formal and informal presentations.
1.2.3. Identify and use verbal, nonverbal and active listening skills to communicate effectively.
1.2.4. Use negotiation and conflict-resolution skills to reach solutions.
1.2.5. Communicate information (e.g., directions, ideas, vision, workplace expectations) for an intended audience and purpose.
1.2.6. Use proper grammar and expression in all aspects of communication.
1.2.7. Use problem-solving and consensus-building techniques to draw conclusions and determine next steps.
1.2.8. Identify the strengths, weaknesses, and characteristics of leadership styles that influence internal and external workplace relationships.
1.2.9. Identify advantages and disadvantages involving digital and/or electronic communications (e.g., common content for large audience, control of tone, speed, cost, lack of non-verbal cues, potential for forwarding information, longevity).
1.2.10. Use interpersonal skills to provide group leadership, promote collaboration and work in a team.
1.2.11. Write professional correspondence, documents, job applications, and resumés.
1.2.12. Use technical writing skills to complete forms and create reports.
1.2.13. Identify stakeholders and solicit their opinions.
1.2.14. Use motivational strategies to accomplish goals.

Strand 1. Business Operations/21st Century Skills

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Outcome 1.3 Business Ethics and Law: Analyze professional, ethical, and legal behavior contributes to continuous improvement in organizational performance and regulatory compliance.

Competencies:

1.3.1. Analyze how regulatory compliance affects business operations and organizational performance.
1.3.2. Follow protocols and practices necessary to maintain a clean, safe, and healthy work environment.
1.3.3. Use ethical character traits consistent with workplace standards (e.g., honesty, personal integrity, compassion, justice).
1.3.4. Identify how federal and state consumer protection laws affect products and services.
1.3.5. Access and implement safety compliance measures (e.g., quality assurance information, safety data sheets [SDSs], product safety data sheets [PSDSs], United States Environmental Protection Agency [EPA], United States Occupational Safety and Health Administration [OSHA]) that contribute to the continuous improvement of the organization.
1.3.6. Identify deceptive practices (e.g., bait and switch, identity theft, unlawful door-to-door sales, deceptive service estimates, fraudulent misrepresentations) and their overall impact on organizational performance.
1.3.7. Identify the labor laws that affect employment and the consequences of noncompliance for both employee and employer (e.g., harassment, labor, employment, employment interview, testing, minor labor laws, Americans with Disabilities Act, Fair Labor Standards Acts, Equal Employment Opportunity Commission [EEOC]).
1.3.8. Verify compliance with computer and intellectual property laws and regulations.
1.3.9. Identify potential conflicts of interest (e.g., personal gain, project bidding) between personal, organizational, and professional ethical standards.

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.4 Knowledge Management and Information Technology: Demonstrate current and emerging strategies and technologies used to collect, analyze, record and share information in business operations.

Competencies:

1.4.1. Use office equipment to communicate (e.g., phone, radio equipment, fax machine, scanner, public address systems).

1.4.2. Select and use software applications to locate, record, analyze, and present information (e.g., word processing, e-mail, spreadsheet, databases, presentation, Internet search engines).

1.4.3. Verify compliance with security rules, regulations and codes (e.g., property, privacy, access, accuracy issues, client, and patient record confidentiality) pertaining to technology specific to the industry pathway.

1.4.4. Use system hardware to support software applications.

1.4.5 Use information technology tools to maintain, secure and monitor business records.

1.4.6 Use an electronic database to access and create business and technical information.

1.4.7 Use personal information management and productivity applications to optimize assigned tasks (e.g., lists, calendars, address books).

1.4.8 Use electronic media to communicate and follow network etiquette guidelines.

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.5 Global Environment: Evaluate how beliefs, values, attitudes, and behaviors influence organizational strategies and goals.

Competencies:

1.5.1. Describe how cultural understanding, cultural intelligence skills and continual awareness are interdependent.
1.5.2. Describe how cultural intelligence skills influence the overall success and survival of an organization.
1.5.3. Use cultural intelligence to interact with individuals from diverse cultural settings.
1.5.4. Recognize barriers in cross-cultural relationships and implement behavioral adjustments.
1.5.5. Recognize the ways in which bias and discrimination may influence productivity and profitability.
1.5.6. Analyze work tasks for understanding and interpretation from a different cultural perspective.
1.5.7. Use intercultural communication skills to exchange ideas and create meaning.
1.5.8. Identify how multicultural teaming and globalization can foster development of new and improved products and services and recognition of new opportunities.

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.6 Business Literacy: Develop foundational skills and knowledge in entrepreneurship, financial literacy and business operations.

Competencies:

1.6.1. Identify business opportunities.
1.6.2. Assess the reality of becoming an entrepreneur, including advantages and disadvantages (e.g., risk versus reward, reasons for success and failure).
1.6.3. Explain the importance of planning your business.
1.6.4. Identify types of businesses, ownership, and entities (i.e., individual proprietorships, partnerships, corporations, cooperatives, public, private, profit, not-for-profit).
1.6.5. Describe organizational structure, chain of command, the roles and responsibilities of the organizational departments, and interdepartmental interactions.
1.6.6. Identify the target market served by the organization, the niche that the organization fills, and an outlook of the industry.
1.6.7. Identify the effect of supply and demand on products and services.
1.6.8. Identify the features and benefits that make an organization's product or service competitive.
1.6.9. Explain how the performance of an employee, a department and an organization is assessed.
1.6.10. Describe the impact of globalization on an enterprise or organization.
1.6.11. Describe how all business activities of an organization work within the parameters of a budget.
1.6.12. Describe classifications of employee benefits, rights, deductions and compensations.

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.7. Entrepreneurship/Entrepreneurs: Analyze the environment in which a business operates, and the economic factors and opportunities associated with self-employment.

Competencies:

1.7.1. Compare and contrast the four types of business ownership (i.e., individual proprietorships, partnerships, corporations, cooperatives).
1.7.2. Explain the role of profit as the incentive to entrepreneurs in a market economy.
1.7.3. Identify the factors that contribute to the success and failure of entrepreneurial ventures.
1.7.4. Assess the roles of nonprofit and for-profit businesses.
1.7.5. Develop a business plan.
1.7.6. Describe life cycles of an entrepreneurial business and an entrepreneur.
1.7.7. Create a list of personal strengths, weaknesses, skills and abilities needed to be successful as an entrepreneur.
1.7.8. Explain pathways used to become an entrepreneur.
1.7.9. Conduct a self-assessment to determine entrepreneurial potential.
1.7.10. Describe techniques for obtaining experience (e.g., apprenticeship, co-operative [co-op] education, work placement, internship, job shadowing) related to an entrepreneurial objective.
1.7.11. Identify initial steps in establishing a business (e.g., limited liability company [LLC], tax ID, permits, insurance, licensing).
1.7.12. Identify resources available to entrepreneurs (e.g., Small Business Administration, mentors, information resources, educational opportunities).
1.7.13. Protect intellectual property and knowledge (e.g., copyright, patent, trademark, trade secrets, processes).

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.8 Operations Management: Plan, organize, and monitor an organization or department to maximize contribution to organizational goals and objectives.

Competencies:

1.8.1. Forecast future resources and budgetary needs using financial documents (e.g., balance sheet demand forecasting, financial ratios).
1.8.2. Select and organize resources to develop a product or a service.
1.8.3. Analyze the performance of organizational activities and reallocate resources to achieve established goals.
1.8.4. Identify alternative actions to take when goals are not met (e.g., changing goals, changing strategies, efficiencies).
1.8.5. Use inventory and control systems to purchase materials, supplies, and equipment (e.g., Last In, First Out [LIFO]; First In, First Out [FIFO]; Just in Time [JIT]; LEAN).
1.8.6. Identify the advantages and disadvantages of carrying cost and Just-in-Time (JIT) production systems and the effects of maintaining inventory (e.g., perishable, shrinkage, insurance) on profitability.
1.8.7. Collect information and feedback to help assess the organization's strategic planning and policymaking processes.
1.8.8. Identify routine activities for maintaining business facilities and equipment.
1.8.9. Develop a budget that reflects the strategies and goals of the organization.
1.8.10. Analyze how business management and environmental management systems (e.g., health, safety) contribute to continuous improvement and sustainability.

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.9 Financial Management: Use financial tools, strategies and systems to develop, monitor and control the use of financial resources to ensure personal and business financial well-being.

Competencies:

1.9.1. Create, analyze and interpret financial documents (e.g., budgets, income statements).
1.9.2. Identify tax obligations.
1.9.3. Review and summarize savings, investment strategies and purchasing options (e.g., cash, lease, finance, stocks, bonds).
1.9.4. Identify credit types and their uses to establish credit.
1.9.5. Identify ways to avoid or correct debt problems.
1.9.6. "Explain how credit ratings and the criteria lenders use to evaluate repayment capacity affect access to loans."
1.9.7. "Review and summarize categories (types) of insurance and identify how insurances can reduce financial risk."
1.9.8. Identify income sources and expenditures.
1.9.9. Compare and contrast different banking services available through financial institutions.
1.9.10. Identify the role of depreciation in tax planning and liability.

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.10 Sales and Marketing: Manage pricing, place, promotion, packaging, positioning, and public relations to improve quality customer service.

Competencies:

1.10.1. Identify how the roles of sales, advertising, and public relations contribute to a company's brand.
1.10.2. Determine the customer's needs and identify solutions.
1.10.3. Communicate features, benefits, and warranties of a product or service to the customer.
1.10.4. Identify the company policies and procedures for initiating product and service improvements.
1.10.5. Monitor customer expectations and determine product/services satisfaction by using measurement tools.
1.10.6. Discuss the importance of correct pricing to support a product or service's positioning in the marketing mix.
1.10.7. Describe the importance and diversity of distribution channels (i.e., direct, indirect) to sell a product.
1.10.8. Use promotional techniques to maximize sales revenues (e.g., advertising, sales promotions, publicity, public relations).
1.10.9. Describe how product mix (e.g., product line, product items) maximize sales revenues, market, share, and profit margin.
1.10.10. Demonstrate sales techniques.

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.11. Principles of Business Economics: Examine and employment principles, concepts, and policies to accomplish organizational goals and objectives.

Competencies:

1.11.1. Identify the economic principles that guide geographic location of an industry's facilities (e.g., relative scarcity, price, quantity of products and services).
1.11.2. Identify the difference between monetary and non-monetary incentives and explain how changes in incentives cause changes in behavior.
1.11.3. Use economic indicators to identify economic trends and conditions (e.g., inflation, interest rate fluctuations, unemployment rates).
1.11.4. Determine how the quality, quantity and pricing of goods and services are affected by domestic and international competition in a market economy.
1.11.5. Analyze factors that affect currency and exchange rates.
1.11.6. Explain how financial markets and government policies influence interest rates (credit ratings/debt ceiling), trade deficits and unemployment.
1.11.7. Describe how economic performance and culture are interdependent.
1.11.8. Identify the relationships between economy, society and environment that lead to sustainability.
1.11.9. Describe how laws and regulations influence domestic and international trade.

Strand 1. Business Operations/21st Century Skills

Learners apply principles of economics, business management, marketing and employability in an entrepreneur, manager and employee role to the leadership, planning, developing and analyzing of business enterprises related to the career field.

Outcome 1.12. Site and Personal Safety Procedures: Follow site and personal safety procedures in specific situations with specialized tools and equipment, evaluate the situation and take corrective action.

Competencies:

1.12.1. Use Occupational Safety and Health Administration (OSHA) defined procedures for identifying employer and employee responsibilities, working in confined spaces, managing worker safety programs, using ground fault circuit interrupters (GFCIs), maintaining clearance and boundaries and labeling.
1.12.2. Interpret safety signs and symbols.
1.12.3 Interpret personal safety rights according to the employee Right to Know plan.
1.12.4. Describe how working under the influence of drugs and alcohol increases the risk of accident, lowers productivity, raises insurance costs and reduces profits.
1.12.5. Identify the location of emergency flush showers, eyewash fountains, Safety Data Sheets (SDSs), fire alarms and exits.
1.12.6. Identify procedures for the handling, storage and disposal of hazardous materials.
1.12.7. Select, use, store, maintain and dispose of personal protective equipment (PPE), appropriate to job tasks, conditions and materials.
1.12.8. Identify safety hazards and take corrective measures.
1.12.9. Identify, inspect and use safety equipment appropriate for the task.
1.12.10. Follow established procedures for the administration of first aid and contact emergency medical personnel when necessary.
1.12.11 Set up for ergonomic workflow.
1.12.12. Apply inspection, rejection criteria, hitch configurations and load handling practices to slings and rigging hardware.
1.12.13. Demonstrate the proper use of American National Standards Institute (ANSI) hand signals.
1.12.14 Identify the source of electrical hazards and use shutdown and established lockout/tag-out procedures.
1.12.15. Select and operate fire extinguishers based on the class of fire.

Strand 2. Electrical/Electronics

Learners apply principles of electricity and electronics related to electronic theory, alternating and direct current, electronic components, electronic skills, digital electronics and power supplies. Knowledge and skills may be applied to fundamentals of electricity, analyzing and evaluating circuits, assembling components into electrical circuits, creating circuits to perform tasks and operations, wiring components to construct and provide power to an electrical system.

Outcome 2.1 **Electrical and Electronic Theory**: Explain electrical and electronic principles and theory.

Competencies

2.1.1 Describe the structure of atoms and their relationship to electricity.
2.1.2 Compare electrical properties and electromagnetic effect.
2.1.3 Explain methods of producing electrical current.
2.1.4 Compare alternating current (AC) and direct current (DC).
2.1.5 Define the units of measurement for voltage, current, power and resistance.
2.1.6 Describe the relationships between voltage, current, resistance and power in circuits.
2.1.7 Determine voltage, current, resistance and power in circuits using Ohm's Law, Kirchhoff's Law and Watt's Law.
2.1.8 Describe the purpose of grounding and common methods used for grounding.
2.1.9 Evaluate frequency and phase for singular and multi-phase systems.
2.1.10 Understand the principles of singular and multi-phase power systems including their operation and applications.
2.1.11 Determine impedance.
2.1.12 Compare peak (PK), root mean square (RMS) and average values.

Strand 2. Electrical/Electronics

Learners apply principles of electricity and electronics related to electronic theory, alternating and direct current, electronic components, electronic skills, digital electronics and power supplies. Knowledge and skills may be applied to fundamentals of electricity, analyzing and evaluating circuits, assembling components into electrical circuits, creating circuits to perform tasks and operations, wiring components to construct and provide power to an electrical system.

Outcome 2.2 **Circuits:** Construct and analyze alternating current (AC) and direct current (DC) circuits.

Competencies

2.2.1 Compare conductors and insulators.
2.2.2 Explain step-up/step-down voltage methods.
2.2.3 Describe lamination and explain why laminations are used.
2.2.4 Identify the function of inductors and capacitors in series and parallel circuits.
2.2.5 Explain the uses of series, parallel and series-parallel circuits.
2.2.6 Construct and troubleshoot series, parallel and series-parallel circuits.
2.2.7 Analyze wiring schematics and diagrams for accuracy, function, and performance characteristics (e.g., time constants, current flow, impedance, signal timing, etc).
2.2.8 Use circuit theorems in circuit analysis (e.g., Maximum power transfer, Thevenin, Source Transformation).
2.2.9 Identify and differentiate between different types of circuits (RC, RL, RCL, etc)
2.2.10 Explain steady-state behavior and how circuits respond under different conditions
2.2.11 Understand and apply the principles of operational amplifiers (Op-Amps) in electronic circuits
2.2.12 Use analysis techniques in circuit analysis (e.g., mesh, loop, superposition, single & double subscript notation).
2.2.13 Analyze the behavior of capacitors and inductors in AC circuits, including time constants and impedance.
2.2.14 Design and implement simple analog filters using capacitors, inductors, and resistors.
2.2.15 Troubleshoot and diagnose faults in AC circuits, identifying common issues such as open circuits, short circuits, faulty components (e.g., capacitors, resistors), and wiring issues.
2.2.16 Explain the role of AC circuits in real-world applications (power supplies, audio amplification, motor control etc)
2.2.17 Explain the role of DC Circuits in real-world applications (XXX)

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Outcome 2.3 **Electronic Components:** Describe the functions and purposes of electronic components.

Competencies

2.3.1 Identify resistor values from color codes or other marks.
2.3.2 Compare resistor compositions and their uses.
2.3.3 Identify symbols for electronic components.
2.3.4 Compare negative positive negative (NPN) and positive negative positive (PNP) bipolar junction transistors (BJT).
2.3.5 Identify types of transistors and diodes and explain their uses (e.g., Darlington pairs, unijunction transistors, Gunn diodes, field effect transistors [FETs] and metal-oxide semiconductor field- effect transistor [MOSFETs], N- and P- channel junction field effect transistors [JFETs]).
2.3.6 Compare the purpose and function of thyristors (e.g., diacs, triacs, and varisters).
2.3.7 Describe the purpose and operation of zener diodes.
2.3.8 Describe the purpose and operation of optical interface devices (e.g., light emitting diodes [LEDs], liquid crystal displays [LCDs]).
2.3.9 Describe the purpose and operation of photovoltaic cells.
2.3.10 Describe the purpose, and operation of photo resistors, photodiodes and phototransistors.
2.3.11 Define surface mount components.
2.3.12 Describe the purpose and operation of audio amplifiers and their frequency response.
2.3.13 Explain the purpose and operation of common emitter (CE) amplifiers, common base (CB) amplifiers and common collector (CC) or emitter follower amplifiers.
2.3.14 Explain the role of operational amplifiers in analog circuits, including their use in amplifiers, filters, and other analog applications.
2.3.15 Design and analyze basic analog signal processing circuits, including amplifiers, oscillators, and mixers.
2.3.16 Understand and apply the principles of noise reduction in analog circuits, including grounding, shielding, and filtering techniques.

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Outcome 2.4 **Electronic Connections:** Connect individual components into an electrical circuit.

Competencies

2.4.1 Define the purpose of a connection and the differences between a good and bad connection.
2.4.2 Describe methods of electrical connections and the purpose for each method.
2.4.3 Select the type of electrical connection for electrical components.
2.4.4 Protect circuit boards from electrostatic discharge (ESD).
2.4.5 Combine components per wiring schematics, block diagrams, and flow charts.
2.4.6 Select and install terminal strip according to wiring diagram and/or schematics.
2.4.7 Design a regulated power supply for powering analog circuits, incorporating voltage regulation and filtering.
2.4.8 Use diagnostic tools to troubleshoot circuits effectively (signal generator, oscilloscope, multimeter etc.)
2.4.9 Understand and apply the use of analog components like voltage-controlled oscillators (VCOs) and phase-locked loops (PLLs) in signal processing.

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Outcome 2.5 Digital Electronics: Create circuits to perform tasks and operations.

Competencies

2.5.1 Identify the numbering systems, codes, arithmetic operations, Boolean operations, and simplification methods used in digital electronics.

2.5.2 Convert number systems (e.g., binary coded decimal (BCD) to decimal, and decimal to BCD) and perform arithmetic operations.

2.5.3 Understand and apply DeMorgan's Theorem to simplify logic expressions and digital circuits using basic logic gates, demonstrating the ability to analyze and modify circuit designs

2.5.4 Describe the purpose and use of logic gates (e.g., discrete and medium scale integration [MSI] gates, latches, flip-flops) and demonstrate understanding through the use of truth tables.

2.5.5 Design and implement combinational logic circuits (e.g., adders, subtractors, multiplexers, demultiplexers, encoders, decoders), including the use of Arithmetic Logic Units (ALUs) for solving arithmetic and logical problems.

2.5.6 Simplify Boolean expressions using methods like Karnaugh Maps (K-Maps) and apply them in the design of combinational logic circuits (e.g., decoders, adders, subtractors, multiplexers).

2.5.7 Design and implement sequential circuits using flip-flops, counters, and shift registers.

2.5.8 Understand and explain the purpose and operation of asynchronous and synchronous counters in digital systems.

2.5.9 Design and troubleshoot digital circuits based on schematics, using both solder and solderless techniques.

2.5.10 Identify and explain the purpose of memory in control systems, including types like RAM, ROM, and EEPROM.

2.5.11 Design and analyze digital-to-analog and analog-to-digital circuits.

2.5.12 Explain the operation of digital buses and demonstrate their use in connecting components in digital systems.

2.5.13 Explain and apply the use of pulsers, logic probes, and other diagnostic tools in troubleshooting digital circuits.

2.5.14 Design a schematic for a digital circuit, ensuring proper functionality and clarity.

2.5.15 Determine fan-out, propagation delays, and their impact on the performance of digital circuits.

2.5.16 Analyze and optimize power consumption in digital circuits, particularly in embedded systems.
2.5.17 Utilize counters in circuits for operations like counting, timing, and data sequencing.
2.5.18 Troubleshoot and modify digital circuits based on schematics and circuit diagrams.
2.5.19 Determine and calculate the output frequency and performance of digital circuits.
2.5.20 Utilize memory in a control system for storing and accessing data.

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Learners apply principles of electricity and electronics related to electronic theory, alternating and direct current, electronic components, electronic skills, digital electronics and power supplies. Knowledge and skills may be applied to fundamentals of electricity, analyzing and evaluating circuits, assembling components into electrical circuits, creating circuits to perform tasks and operations, wiring components to construct and provide power to an electrical system.

Outcome 2.6 **Cabling and Wiring:** Connect components to construct low-voltage, data and communication systems using coaxial or fiber optic cables and twisted pair or balanced wires.

Competencies

2.6.1 Describe the types, purpose, and characteristics of cables and wires and their purpose

2.6.2 Select methods for splicing and terminating cables and wires (e.g., terminal strips, and crimp connectors).

2.6.3 Splice and terminate cables and wires.

2.6.4 Test cables and wires.

Outcome 2.7 **Power Supplies:** Provide power to electrical circuits.

Competencies

2.7.1 Identify the differences between transformer-powered supplies and line-connected supplies.

2.7.2 Select and install filters.

2.7.3 Construct and install regulated power supplies.

2.7.4 Select and install fuses and circuit breakers.

2.7.5 Select and construct half-wave, full-wave and bridge rectifiers.

2.7.6 Select and install power conditioning, isolation transformers, surge suppressors and uninterruptible power supplies.

2.7.7 Design, analyze, and demonstrate an understanding of basic filter circuits (low-pass, high-pass, band-pass, and band-stop filters).

2.7.8 Design and implement AC to DC conversion circuits, including full-wave, half-wave, and bridge rectifiers.

2.7.9 Understand and apply the principles of inverters and DC-AC conversion in power electronics.

Strand 2. Electrical/Electronics

Learners apply principles of electricity and electronics related to electronic theory, alternating and direct current, electronic components, electronic skills, digital electronics and power supplies. Knowledge and skills may be applied to fundamentals of electricity, analyzing and evaluating circuits, assembling components into electrical circuits, creating circuits to perform tasks and operations, wiring components to construct and provide power to an electrical system.

Outcome 2.8 Battery Technology: Understand batteries its principles and applications.

Competencies

2.8.1 Describe how a battery works, including how electrons and ions move during charging and discharging.

2.8.2 Compare primary and secondary batteries, including lithium-ion (e.g., LFP, NMC), lead-acid, and nickel-based types, based on performance and applications.

2.8.3 Calculate and interpret battery performance values such as energy density, power density, C-rate, efficiency, and internal resistance using given data.

2.8.4 Read and interpret charge and discharge graphs to determine battery capacity, cycle life, and signs of performance loss.

2.8.5 Describe the purpose of a Battery Management System (BMS) and interpret information related to state of charge (SOC), state of health (SOH), and cell balancing.

2.8.6 Select an appropriate battery type for a specific application based on environment, power needs, lifespan, and safety requirements.

2.8.7 Identify common battery hazards (e.g., short circuit, overcharging, thermal runaway) and determine appropriate safety measures.

2.8.8 Describe new and emerging battery technologies and explain how they may impact manufacturing and industry.

Strand 2. Electrical/Electronics

Learners apply principles of electricity and electronics related to electronic theory, alternating and direct current, electronic components, electronic skills, digital electronics and power supplies. Knowledge and skills may be applied to fundamentals of electricity, analyzing and evaluating circuits, assembling components into electrical circuits, creating circuits to perform tasks and operations, wiring components to construct and provide power to an electrical system.

Outcome 2.9 Battery Production: Explain battery production process, considering material usage and environmental impact.

Competencies

2.9.1 Explain how batteries store and disperse energy.

2.9.2 Analyze the major stages of lithium-ion battery manufacturing, including material preparation, electrode fabrication, cell assembly, electrolyte filling, formation cycling, and final testing.

2.9.3 Explain how formation cycling helps stabilize the battery and improves its long-term performance.

2.9.4 Interpret battery quality data, such as electrical resistance, leak detection, temperature monitoring, and end-of-line performance tests.

2.9.5 Evaluate materials for battery components (anode, cathode, separator, electrolyte) based on properties like conductivity, stability, manufacturability, cost, and environmental impact.

2.9.6 Select the most suitable battery system based on the operating environment, energy demands, and applicable regulations.

2.9.7 Analyze battery module and pack assembly, including how cells are connected, thermal management strategies, safety isolation, and pack-level testing.

Strand 3. Mechanical Systems

Learners apply principles of motors and power, hydraulics and pneumatics, mechanical drives, pumping systems, and cleanroom vacuum systems. They gain essential knowledge and skills in installing, maintaining, and troubleshooting various mechanical systems used in engineering and manufacturing.

Outcome 3.1 **Motors and Power:** Install motors, variable-frequency drives (VFD), and power wiring.

Competencies

3.1.1 Identify types and components of single phase and three phase motors.
3.1.2 Interpret motor nameplate information and motor specifications.
3.1.3 Calculate motor loads.
3.1.4 Determine motor rotation needed for the installed load and explain the process for reversing rotation (i.e., three phase and single phase).
3.1.5 Interpret schematics and control diagrams for building a motor circuit.
3.1.6 Wire single phase and three phase circuits and install motor control devices (e.g., contactors, starters, variable-frequency drive (VFD) and motor speed controls).
3.1.7 Explain the starting sequence of motor components within a given circuit.
3.1.8 Troubleshoot and repair motor starting systems to verify operation according to schematics and control diagrams.
3.1.9 Describe how programmable controllers can be used to control single speed motors and variable speed motor applications.

Strand 3. Mechanical Systems

Learners apply principles of motors and power, hydraulics and pneumatics, mechanical drives, pumping systems, and cleanroom vacuum systems. They gain essential knowledge and skills in installing, maintaining, and troubleshooting various mechanical systems used in engineering and manufacturing.

Outcome 3.2 Hydraulics and Pneumatics Systems: Install, maintain, and troubleshoot Hydraulic and Pneumatic systems

Competencies

3.2.1 Understand and explain the fundamental principles of hydraulics and pneumatics system (e.g., Pressure, Flow, and Force)

3.2.2 Identify the major components of hydraulics and pneumatics systems (e.g., pumps, cylinders, valves, and compressors)

3.2.3 Describe the properties of fluids used in hydraulics systems including viscosity, density, and compressibility.

3.2.4 Describe the properties of gases used in pneumatic systems including viscosity, density, and compressibility.

3.2.5 Interpret a basic schematic of a basic hydraulic or pneumatic system identifying the components of that system within the schematic

3.2.6 Calculate pressures, forces, and fluid flow rates in hydraulic and pneumatic systems

3.2.7 Explain the transfer of energy in hydraulic and pneumatic systems, including the concepts of work, power, and efficiency.

3.2.8 Identify present applications of hydraulics and pneumatic systems in industry.

3.2.9 Troubleshoot common issues in hydraulic and pneumatic systems (e.g., leaks, pressure drops, and component failures)

3.2.10 Select a fluid power system based on project needs (e.g., pressure, flow, temperature, dissipation, filtration, fluid, maintenance).

3.2.11 Explain the forces exerted by fluids on plane and curved boundaries

3.2.12 Differentiate between laminar and turbulent flow based on flow characteristics, velocity profiles, and Reynolds number, and explain their impact on fluid systems

3.2.13 Interpret absolute and gauge pressure measurements and convert between them using standard reference pressures in practical applications

3.2.14 Apply Pascal's Law to show how pressure moves through a fluid and how it can be used to increase force in hydraulic systems

3.2.15 Use Bernoulli's Equation to evaluate pressure, velocity, and elevation relationships in flowing fluids and solve basic engineering problems.

Strand 3. Mechanical Systems

Learners apply principles of motors and power, hydraulics and pneumatics, mechanical drives, pumping systems, and cleanroom vacuum systems. They gain essential knowledge and skills in installing, maintaining, and troubleshooting various mechanical systems used in engineering and manufacturing.

Outcome 3.3 **Mechanical Drives Systems:** Install, maintain, and monitor mechanical drives systems.

Competencies

3.3.1 Compare types of gears, couplings, belts and chains and describe their uses.
3.3.2 Perform shaft alignment on rotating equipment.
3.3.3 Select bearings for specific applications.
3.3.4 Calculate or obtain speed and torque ratios for belt and chain drives per design specifications.
3.3.5 Install and align power transmissions systems.
3.3.6 Perform power transmissions systems maintenance.
3.3.7 Monitor power transmissions systems.
3.3.8 Troubleshoots for power transmission systems problems and inefficiencies.

Strand 3. Mechanical Systems

Learners apply principles of motors and power, hydraulics and pneumatics, mechanical drives, pumping systems, and cleanroom vacuum systems. They gain essential knowledge and skills in installing, maintaining, and troubleshooting various mechanical systems used in engineering and manufacturing.

Outcome 3.4 **Pumping Systems:** Install, maintain, and troubleshoot pumps and pumping systems.

Competencies

3.4.1 Understand and explain the fundamental principles of pumps and pumping systems.
3.4.2 Identify the major components of pumps and pumping systems.
3.4.3 Interpret a basic schematic of a pumping system identifying the components of that system within the schematic
3.4.4 Interpret pump curves.
3.4.5 Calculate flow, head/pressure and efficiency.
3.4.6 Compare types of positive and non-positive displacement pumps and their respective functions.
3.4.7 Align precision and non-precision couplings.
3.4.8 Disassemble and assemble pumping stations.
3.4.9 Troubleshoot pump system failure conditions (e.g., cavitation).

Strand 3. Mechanical Systems

Learners apply principles of motors and power, hydraulics and pneumatics, mechanical drives, pumping systems, and cleanroom vacuum systems. They gain essential knowledge and skills in installing, maintaining, and troubleshooting various mechanical systems used in engineering and manufacturing.

Outcome 3.5 Cleanroom Vacuum Systems: Understand, operate, and troubleshoot vacuum systems used in semiconductor manufacturing.

Competencies

3.5.1 Explain the operational mechanisms and process use of vacuum pumps in the semiconductor industry (i.e., wafer transport, dry clean or etching with reactive ion etch, thin film deposition, ion implantation).
3.5.2 Differentiate atmosphere, course/rough/low vacuum, high vacuum and ultra-high vacuums.
3.5.3 Explain vacuum measurement on a roughing pump and record pressures during a roughing pump-down.
3.5.4 Summarize high vacuum pumps evolution and applications.
3.5.5 Distinguish why high-volume systems may have more than one roughing pump.
3.5.6 Describe series and/or parallel vacuum pump use with qualitative and quantitative examples.
3.5.7 Use charts to compare pumping speed and ultimate pressure.
3.5.8 Differentiate crossover pressure with the use of high vac and low vac pump systems.
3.5.9 Classify types of pressure gauges, measurement ranges, plumbing connections
3.5.10 Describe roughing and high vacuum pump components (e.g. gauges, valves, fittings).
3.5.11 Explain how a high vacuum pump works with a roughing pump and measure pressure during pump-down, observing crossover pressure.

Strand 4. Materials Joining

Learners apply principles of physics and metallurgy to join materials and test joints. Knowledge and skills may be applied to arc welding processes, non-arc welding processes, testing and inspection and thermal cutting.

Outcome 4.1 **Metallurgy of Welding:** Apply the metallurgy of welding to the processes of joining metal.

Competencies

4.1.1 Explain the difference between ferrous and nonferrous alloys
4.1.2 Identify and explain the differences between various metals
4.1.3 Identify different hardness of material (Carbon content) (Mild steel vs hard steel)
4.1.4 Explain how carbon content impacts steel
4.1.5 Describe how pre and post heat treatments affect weld quality
4.1.6 Describe the conductivity & thermal conductivity of different metals
4.1.7 Understand the process of hard facing and the benefits to weld durability through the process
4.1.8 Determine materials weldability and the appropriate techniques that can be used
4.1.9 Knowledge of welding dissimilar metals and the processes used to achieve this.

Strand 4. Materials Joining

Learners apply principles of physics and metallurgy to join materials and test joints. Knowledge and skills may be applied to arc welding processes, non-arc welding processes, testing and inspection and thermal cutting.

Outcome 4.2 **Arc Welding Processes:** Perform types of welds in the six positions using arc welding processes.

Competencies

4.2.1 Identify and select different types of joints for product specifications
4.2.2 Select the types of weld required for product specifications.
4.2.3 Explain electrode and filler metal classification systems and procedures for handling and storing.
4.2.4 Select an arc welding process based on product specifications.
4.2.5 Join materials using the shielded metal arc welding (SMAW) process.
4.2.6 Join materials using the gas metal arc welding (GMAW) process.
4.2.7 Join materials using the flux core arc welding (FCAW) process.
4.2.8 Join materials using the submerged arc welding (SAW) process.
4.2.9 Join materials using the gas tungsten arc welding (GTAW) process.
4.2.10 Join materials using the arc stud welding process.
4.2.11 Identify and position the weldment in the correct position and know what those positions are.
4.2.12 Set the appropriate parameters of the machine according to weld requirements

Strand 4. Materials Joining

Learners apply principles of physics and metallurgy to join materials and test joints. Knowledge and skills may be applied to arc welding processes, non-arc welding processes, testing and inspection and thermal cutting.

Outcome 4.3 **Non-Arc Material Joining Processes:** Perform types of non-arc material joining processes in the six positions.

Competencies

4.3.1 Select the types of material required for product specifications.
4.3.2 Select non-arc welding processes based on product specifications.
4.3.3 Join materials using the resistance welding (RW) process.
4.3.4 Join materials using the oxy-fuel gas welding process.
4.3.5 Describe the types and applications of solid-state bonding processes.
4.3.6 Describe the ultrasonic welding process.
4.3.7 Describe the friction stir process.
4.3.8 Describe the high energy density fusion welding processes.
4.3.9 Describe the process for joining plastics and the techniques used.
4.3.10 Join materials using the adhesive bonding of parts technique.
4.3.11 Join materials using the brazing and soldering processes.

Strand 4. Materials Joining

Learners apply principles of physics and metallurgy to join materials and test joints. Knowledge and skills may be applied to arc welding processes, non-arc welding processes, testing and inspection and thermal cutting.

Outcome 4.4 Testing and Inspection: Test and inspect joints and weld structures.

Competencies

4.4.1 Identify the factors considered in weld quality.
4.4.2 Conduct a visual defect examination.
4.4.3 Conduct destructive weldment testing.
4.4.4 Describe the dye penetrant examination process and interpret the results
4.4.5 Describe the radiographic examination process and interpret the results
4.4.6 Describe the eddy current examination process and interpret the results
4.4.7 Describe the phased array examination process and interpret the results
4.4.8 Analyze weld structure test results to determine weld quality.
4.4.9 Describe emerging non-destructive examination process related to quality testing.
4.4.10 Differentiate between destructive and non-destructive welding examinations
4.4.11 Identify the and explain different discontinuity of welds and the issues they can cause
4.4.12 Identify and explain different welding defects and the issues they can cause
4.4.13 Describe the various tools that are needed for visual inspection and examination
4.4.14 Explain what tensil strength is and how you can test for it.
4.4.15 Conduct a spark test and interpret the results to identify the metal.

Strand 4. Materials Joining

Learners apply principles of physics and metallurgy to join materials and test joints. Knowledge and skills may be applied to arc welding processes, non-arc welding processes, testing and inspection and thermal cutting.

Outcome 4.5 Cutting Processes: Cut materials using cutting processes.

Competencies

4.5.1 Identify types of materials to be cut.
4.5.2 Identify the characteristics of the cut (e.g. bevels, miters, angles) and finish (e.g., machined, grind, rolled).
4.5.3 Select a cutting process based on product specifications.
4.5.4 Cut materials using the plasma arc cutting (PAC) process.
4.5.5 Cut and gouge materials using the air carbon arc (CAC-A) process.
4.5.6 Cut materials using manual and machine-guided oxy-fuel processes.
4.5.7 Cut materials using advanced cutting systems (e.g., plasma computer-aided controls, computer numeric controls [CNC], laser).
4.5.8 Cut materials using the thermal cutting process.
4.5.9 Demonstrate scarfing and washing of metals.

Strand 4. Materials Joining

Learners apply principles of physics and metallurgy to join materials and test joints. Knowledge and skills may be applied to arc welding processes, non-arc welding processes, testing and inspection and thermal cutting.

Outcome 4.6 **Fabrication:** Fabricate parts and weldment using fabrication equipment and tools.

Competencies

4.6.1 Evaluate material structures and equipment and plan the method of repair.
4.6.2 Evaluate project design and identify welding type to meet the specifications to plan the method of fabrication.
4.6.3 Lay out and cut materials.
4.6.4 Shape stock through bending, cutting, drilling and filing.
4.6.5 Form and assemble material through cutting and bending.
4.6.6 Edge material through rolling turning, beading and crimping.
4.6.7 Identify various methods of fastening materials.
4.6.8 Fasten material using a range of hardware.
4.6.9 Join material using a range of adhesives.
4.6.10 Process cold metals through tapping, threading, torquing and smoothing.
4.6.11 Compare surface coatings and apply them under appropriate environmental conditions.
4.6.12 Explain and demonstrate the process of squaring and fixturing.

Strand 4. Materials Joining

Learners apply principles of physics and metallurgy to join materials and test joints. Knowledge and skills may be applied to arc welding processes, non-arc welding processes, testing and inspection and thermal cutting.

Outcome 4.7 **Certification of Welding:** Learners demonstrate a knowledge of welding certifications and licenses to be successful in the field.

Competencies

4.7.1 Identify welding codes and standards and their importance to the workplace
4.7.2 Differentiate between welding codes and standards
4.7.3 Compare the different codes provided by the welding industry (Ex. API, ASME, AWS).
4.7.4 Understand the necessary skills to achieve different welding qualifications and certifications
4.7.5 Differentiate between welding qualifications and welding certifications
4.7.6 Describe the necessary experience to become a CWI
4.7.7 Describe the certifications and qualifications to work in a variety of industries
4.7.8 Perform qualification or certification exam based on code specifications

Strand 5. Design and Development

Learners apply principles of the engineering design process, using sketching and drawing, computer-aided drafting and modeling, production and process design, and print interpretation. They gain essential knowledge and skills in analyzing and solving design problems, creating and interpreting technical drawings and models, selecting appropriate materials, and planning and evaluating production processes.

Outcome 5.1 The Design Process: Use the engineering design process and quality assurance principles to analyze and solve design problems.

Competencies

5.1.1 Define the goal of a design
5.1.2 Describe the role of research, development and experimentation in design problem solving.
5.1.3 Conduct an investigation to identify customer needs, constraints and criteria.
5.1.4 Develop multiple solutions and select an approach.
5.1.5 Develop a design proposal and make a model/prototype.
5.1.6 Evaluate and redesign a prototype using collected data.
5.1.7 Use process planning and improvement tools to manage the life cycle of a product.
5.1.8 Identify the potential concept and design flaws (e.g., concept model corrections, audit documentation using Design Failure Mode Effect Analysis [DFMEA]).
5.1.9 Compare design considerations for product recycling or disposal for the end of a product's life cycle.
5.1.10 Document progress and capture ideas during the development phase.
5.1.11 Develop a design using the most environmentally friendly practices available to create the product

Strand 5. Design and Development

Learners apply principles of the engineering design process, using sketching and drawing, computer-aided drafting and modeling, production and process design, and print interpretation. They gain essential knowledge and skills in analyzing and solving design problems, creating and interpreting technical drawings and models, selecting appropriate materials, planning and evaluating production processes.

Outcome 5.2 **Sketching, Drawing, and Visualization:** Conceptualize, sketch, and draw design projects and components.

Competencies

5.2.1 Compare & contrast technical sketches and drawings.
5.2.2 Sketch possible solutions to an existing design problem.
5.2.3 Apply annotations on sketches and drawings.
5.2.4 Sketch geometric forms and shapes.
5.2.5 Translate abstract thoughts into tangible designs
5.2.6 Communiate design technical drawings to to present a design solution
5.2.7 Describe geometric constraints (e.g., geometric dimension and tolerancing [GD&T], run out, location, and form).
5.2.8 Select a view to graphically communicate a design solution.

Strand 5. Design and Development

Learners apply principles of the engineering design process, using sketching and drawing, computer-aided drafting and modeling, production and process design, and print interpretation. They gain essential knowledge and skills in analyzing and solving design problems, creating and interpreting technical drawings and models, selecting appropriate materials, and planning and evaluating production processes.

Outcome 5.3 Computer-Aided Drafting and Modeling: Computer-aided Drafting and Modeling to illustrate the design of projects and components.

Competencies

5.3.1 Introduce manufacturing processes to computer-aided modeling (e.g., casting, molding, forming, separating, conditioning, assembling, finishing, rapid prototyping, 3-D printing).
5.3.2 Evaluate a sketch and generate a model utilizing three-dimensional modeling.
5.3.3 Analyze assembly constraints and successfully construct an assembly drawing.
5.3.4 Use part libraries effectively during the assembly modeling process.
5.3.5 Employ subassemblies during the production of assemblies.
5.3.6 Verify drive constraints that simulate the motion of parts in assemblies.
5.3.7 Adapt design concepts during the development of sketches, drawings, features, parts, and assemblies to meet new product specifications.
5.3.8 Translate a three-dimensional drawing or model into corresponding orthographic drawing views.
5.3.9 Evaluate a model for design imperfections.
5.3.10 Create and interpret auxiliary views, orthographic projections, isometric drawings, oblique drawings, and perspective drawings.
5.3.11 Create a sectional view drawing.
5.3.12 Illustrate the types of breaks and symbols used in drawing sectional and auxiliary views.
5.3.13 Produce a reverse-engineered drawing from a solid object.
5.3.14 Add technical elements (e.g., parts lists, titles, finishes, tolerances, specifications, hidden surfaces) to drawings.
5.3.15 Apply tolerancing techniques and dimensioning to the computer aided design process.

Strand 5. Design and Development

Learners apply principles of the engineering design process, using sketching and drawing, computer-aided drafting and modeling, production and process design, and print interpretation. They gain essential knowledge and skills in analyzing and solving design problems, creating and interpreting technical drawings and models, selecting appropriate materials, planning and evaluating production processes.

Outcome 5.4 Material Selection: Select materials for design projects and components.

Competencies:

5.4.1 Compare advantages of materials used in manufacturing based on physical properties.
5.4.2 Identify the production processes used to create inputs.
5.4.3 Determine the appropriate material to be used to create a product considering production process factors and category of material(e.g., organic materials, metals, polymers, ceramics and composites).
5.4.4 Evaluate the types and magnitude of stresses and forces.
5.4.5 Analyze material properties by destructive and nondestructive tests.
5.4.6 Select materials for a given application based on specified criteria (e.g., cost, availability, manufacturability).
5.4.7 Analyze the strength of a design using a simulation.
5.4.8 Use a material and develop a product.

Strand 5. Design and Development

Learners apply principles of the engineering design process, using sketching and drawing, computer-aided drafting and modeling, production and process design, and print interpretation. They gain essential knowledge and skills in analyzing and solving design problems, creating and interpreting technical drawings and models, selecting appropriate materials, planning and evaluating production processes.

Outcome 5.5 Production and Process Design: Identify and evaluate production and process design.

Competencies:

5.5.1 Explain methods of forging, extrusions, casting, and forming for metal manufacturing processes
5.5.2 Explain plastic manufacturing processes, including molding.
5.5.3 Determine appropriate mold design necessary for the production process
5.5.4 Use process planning and improvement tools (e.g., flowcharts, diagrams, design for manufacturability [DFM]).
5.5.5 Identify the planning and process procedures for production (e.g., corrective preventive actions, audit documentation, Process Failure Mode Effect Analysis [PFMEA]).
5.5.6 Determine critical characteristics and establish quality controls.
5.5.7 Employ project scheduling techniques (e.g., critical path methodology [CPM], project evaluation and review technique [PERT]).
5.5.8 Identify criteria and constraints and determine how those will affect the design of the production process.
5.5.9 Estimate time, tooling, product packaging and material costs.
5.5.10 Monitor performance and compared to time, tool and material cost estimates.
5.5.11 Adjust the production as necessary to respond to variations in the manufacturing process.
5.5.12 Develop a packaging design that prepares a product for shipping.

Outcome 5.6 Layout and Planning: Plan a machining process.

Competencies:

5.6.1 Determine product requirements, dimensions and tolerances from drawing and specifications.
5.6.2 Determine process steps (e.g., cut, drill, turn, mill, grind, heat treat).
5.6.3 Plan individual process steps based on industry standards (e.g., manufacturers' specifications, machining standards).
5.6.4 Schedule machining equipment as required.
5.6.5 Determine the appropriate manufacturing technique that should be ulitized when creating the product

Strand 5. Design and Development

Learners apply principles of the engineering design process, using sketching and drawing, computer-aided drafting and modeling, production and process design, and print interpretation. They gain essential knowledge and skills in analyzing and solving design problems, creating and interpreting technical drawings and models, selecting appropriate materials, planning and evaluating production processes.

Outcome 5.7 **Blueprint Interpretation:** Read, interpret, and utilize blueprints to produce accurate products.

Competencies:

5.7.1 Identify and interpret standard symbols used in blueprints.
5.7.2 Demonstrate the ability to read and convert measurements from scaled drawings.
5.7.3 Differentiate between various line types (e.g., solid, dashed) and their meanings in a blueprint.
5.7.4 Analyze and interpret dimensions, tolerances, and annotations effectively.
5.7.5 Utilize reference notes and legends to clarify details and specifications in blueprints.
5.7.6 Utilize a blueprint to produce a product
5.7.7 Interpret work from multiview drawings, and to visualize shapes and objects in multiple views.

Outcome 5.8 **Schematic Interpretation:** Read, interpret, and utilize schematics to produce accurate products.

Competencies

5.8.1 Identify and interpret standard symbols used in schematics.
5.8.2 Recognize and label key components and systems within a schematic
5.8.3 Trace the flow of systems of schematic diagrams.
5.8.4 Utilize reference notes and legends to clarify details and specifications of schematics.
5.8.5 Identify discrepancies or errors in a schematic.
5.8.6 Utilize a schematic to produce a product
5.8.7 Differentiate between different styles and standards in schematics (e.g., international, US)

Strand 6. Precision and Advanced Machining

Learners apply principles of subtractive and additive manufacturing, tooling, CNC machining, and semiconductor manufacturing. They gain essential knowledge and skills in performing various manufacturing processes, selecting and configuring appropriate tools and equipment, and understanding advanced manufacturing production technologies.

Outcome 6.1 Subtractive Manufacturing: Perform subtractive manufacturing using a variety of methods and techniques

Competencies:

6.1.1 Describe the steps of the subtractive manufacturing (e.g., pre-processing processing and post-processing).
6.1.2 Identify the type of material, tooling, and subtractive method required to meet product specifications
6.1.3 Select appropriate machine, cutting tool, work holding device, speeds, cutting fluids, and end of arm tooling required to produce the part
6.1.4 Configure the equipment.
6.1.5 Prepare work pieces for manufacturing
6.1.6 Manufacture the material utilizing the necessary method, tooling, and material to meet product specifications
6.1.7 Inspect the work to meet requirements.
6.1.8 Perform subtractive manufacturing for rapid prototyping and customization.

Outcome 6.2 Additive Manufacturing: Apply standard practices of additive manufacturing.

Competencies

6.2.1 Describe the steps of the additive manufacturing (e.g., pre-processing processing and post-processing).
6.2.2 Identify the type of material, tooling, and additive method required to meet product specifications
6.2.3 Select appropriate machine, work holding device, speeds and end of arm tooling required to produce the part
6.2.4 Configure the additive manufacturing equipment.
6.2.5 Prepare work pieces for manufacturing
6.2.6 Manufacture the material utilizing the necessary method, tooling, and material to meet product specifications
6.2.7 Perform additive manufacturing for rapid prototyping and customization.

Strand 6. Precision and Advanced Machining

Learners apply principles of subtractive and additive manufacturing, tooling, CNC machining, and semiconductor manufacturing. They gain essential knowledge and skills in performing various manufacturing processes, selecting and configuring appropriate tools and equipment, and understanding advanced manufacturing production technologies.

Outcome 6.3 Tooling: Identify necessary and appropriate tooling to be used in production

Competencies:

6.3.1 Classify various types of tooling fixtures used in manual and CNC operations (Drill bits, Vises, Bores, Jigs etc.)

6.3.2 Identify various types of materials used in machining tools and tooling components (e.g., HSS, carbide, ceramics)

6.3.3 Describe the functionality and purpose of common tooling.

6.3.4 Select appropriate tooling based on job specifications, material type, tolerances, and machining processes.

6.3.5 Design or configure custom tooling or fixturing solutions to meet operational and job requirements.

6.3.6 Perform setup, installation, and verification of tooling in mills, lathes, and CNC machines.

6.3.7 Evaluate the effectiveness and performance of machining tooling.

6.3.8 Select cutting equipment, tool-holding devices, speeds, feeds, and cutting fluids.

Strand 6. Precision and Advanced Machining

Learners apply principles of subtractive and additive manufacturing, tooling, CNC machining, and semiconductor manufacturing. They gain essential knowledge and skills in performing various manufacturing processes, selecting and configuring appropriate tools and equipment, and understanding advanced manufacturing production technologies.

Outcome 6.4 Computer Numerical Control (CNC) Machining: Apply standard practices of CNC operations and part inspection.

Competencies:

6.4.1 Identify CNC machine components and controllers.
6.4.2 Plan a CNC production process for jobs in a machining cell.
6.4.3 Create and edit CNC programs (e.g., G-code, [CAM]) for machine operations according to job specifications, dimensions and tolerances
6.4.4 Create a tool setup sheet.
6.4.5 Work from a process sheet and part print.
6.4.6 Set up and operate CNC machines
6.4.7 Monitor the operations of a machining cell and troubleshoot problems that arise.
6.4.8 Verify part quality against job specifications.

Strand 6. Precision and Advanced Machining

Learners apply principles of subtractive and additive manufacturing, tooling, CNC machining, and semiconductor manufacturing. They gain essential knowledge and skills in performing various manufacturing processes, selecting and configuring appropriate tools and equipment, and understanding advanced manufacturing production technologies.

Outcome 6.5 **Semiconductors:** Understand, describe, and apply semiconductor manufacturing processes and technologies.

Competencies

6.5.1 Describe a semiconductor product, such as a silicon wafer, and its relevance to other products/technologies.
6.5.2 Explain the history of integrated circuit technology with a focus on function, size, power usage, and application.
6.5.3 Describe semiconductor processing, tools and chemistry.
6.5.4 Describe how a wafer is made.
6.5.5 Describe the processes performed at a semiconductor fabrication facility used in the manufacturing of integrated circuits (IC).
6.5.6 Describe the thin film sputtering process.
6.5.7 Describe photolithography processing and purpose of the “photoresist.”
6.5.8 Describe basic processes and tools involved in semiconductor manufacturing wet etching.
6.5.9 Describe basic processes and tools involved in semiconductor manufacturing dry etching.
6.5.10 Describe basic processes and tools involved in semiconductor manufacturing diffusion.
6.5.11 Describe basic processes and tools involved in semiconductor manufacturing thin film disposition (PVD, CVD).
6.5.12 Describe how cleaning, thin film deposition, etching, and photolithography are used to create multiple layers that constitute the fabrication of an integrated circuit (IC).
6.5.13 Describe basic processes and tools in Chemical Mechanical Planarization (CMP).
6.5.14 Describe the final steps in a wafer IC production process.

Strand 7. Computer Integrated Manufacturing

Learners apply the principles of computer integrated manufacturing related to robotics, programmable logic controllers and automated systems.

Outcome 7.1 Robotic Fundamentals: Apply robotics fundamentals.

Competencies:

7.1.1 Identify the components of a robot system and explain their roles in the robot's operation cycle.

7.1.2 Understand applications of robot components and controllers. (e.g. sensors, motors, actuators, endofactor etc.)

7.1.3 Select type of industrial robot to meet specific applications.

7.1.4 Use job specifications to create programs for robot operations, sensors and feeder systems.

7.1.5 Plan, program and test a robot using teach pendant and simulation software.

7.1.6 Identify the robot's payload and identify the concepts of payload weight and moment of inertia to select an appropriate robot.

7.1.7 Use robot speed specifications to calculate estimated cycle times for sample tasks.

7.1.8 Direct robot to home position using absolute and incremental coordinates.

7.1.9 Compare robotic applications and processes (e.g., palletizing, vision, pick and place, welding).

7.1.10 Identify the robot's work envelope and apply the concepts of reach and articulation to evaluate whether a robot is suited to an application.

7.1.11 Analyze the performance and troubleshoot the operation of a robot.

Strand 7. Computer Integrated Manufacturing

Learners apply the principles of computer integrated manufacturing related to robotics, programmable logic controllers and automated systems.

Outcome 7.2 Robotic Operation: Plan and operate robotic production processes.

Competencies:

7.2.1 Perform controller startup and shutdown.
7.2.2 Operate a teach pendant and pendant menu.
7.2.3 Use coordinates or motion functions to execute robotic processes.
7.2.4 Analyze alarm and event data, investigate anomalies, and take appropriate action to resolve issues
7.2.5 Select, display, and run a robotic program.
7.2.6 Modify command positions (i.e., touching-up points).
7.2.7 Explain both motion and non-motion instructions (i.e., control instructions, arithmetic instructions, and input/output instructions).
7.2.8 Identify robotic applications and processes (e.g., pick and place, welding).
7.2.9 Describe common end of arm tooling.
7.2.10 Explain how payload requirements impact robot operation
7.2.11 Describe Cartesian space, the Right-Hand rule and how locations are represented in three-dimensional space.
7.2.12 Determine home position using absolute and incremental coordinates (e.g., fixed and floating zero).
7.2.13 Analyze the information contained in positional data.
7.2.14 Perform robot I/O analysis and manipulation.
7.2.15 Determine application suitability using work envelop, reach and articulation.
7.2.16 Explain methods of establishing a Tool-Center Point (TCP) or Tool-Control Point (TCP)
7.2.17 Identify and explain the function of robotic hardware (switches, sensors, proximity sensors)

Strand 7. Computer Integrated Manufacturing

Learners apply the principles of computer integrated manufacturing related to robotics, programmable logic controllers and automated systems.

Outcome 7.3 Industrial Robotic Programming: Write, edit and test robotic programming.

Competencies:

7.3.1 Create, modify, and test robotic programs (e.g., second home, toolpath, non-motion commands).
7.3.2 Program macro and micro instructions, conditional statements, and arithmetic variables and instructions.
7.3.3 Program, monitor and operate inputs and outputs.
7.3.4 Create and set up tool and user frames to define reference points for robot end effectors and coordinate systems
7.3.5 Create and manage payload schedules, configuring and optimizing robots to handle varying weights, materials, and conditions.
7.3.6 Create and configure global and local positions for robotic systems by defining and adjusting coordinates creating precise robotic movements.
7.3.7 Configure and integrate I/O systems in robotic applications by setting up devices like sensors and actuators to ensure communication with external automation systems (PLCs).
7.3.8 Calibrate and modify tool control point Tool Center Point (TCP).
7.3.9 Describe the use of subroutines.
7.3.10 Perform data manipulation (e.g., counters, data tables, data registers).
7.3.11 Describe the various file types used for import/export of data.
7.3.12 Upload and download data between robotic simulation and a real robot.
7.3.13 Compare the differences between programming in robotic simulation and programming a physical robot.
7.3.14 Perform a robotic simulation to verify reach, cycle time, interference and workcell layout.

Strand 7. Computer Integrated Manufacturing

Learners apply the principles of computer integrated manufacturing related to robotics, programmable logic controllers and automated systems.

Outcome 7.4 **Programmable Logic Controllers (PLCs):** Program, install, and monitor digital computers used for automation of electromechanical processes to perform tasks.

Competencies:

7.4.1 Describe the use of Programmable Logic Circuits (PLC) in manufacturing automation.
7.4.2 Identify programmable logic controller (PLC) hardware components, including relays, relay ladder logic, input/output modules, and communication interfaces
7.4.3 Design a programmable logic controller (PLC) program incorporating timers, counters, sequencers, comparators, and block transfers.
7.4.4 Demonstrate an understanding of number systems used in Programmable Logic Controllers (PLCs) binary, octal, decimal, and hexadecimal systems).
7.4.5 Develop, apply and execute a ladder logic program.
7.4.6 Design a motor control program using manual and automatic modes.
7.4.7 Monitor and troubleshoot a network and hardwired system with a programmable logic controller (PLC).
7.4.8 Monitor and troubleshoot programmable logic controller (PLC) operation (e.g., I/O forcing)
7.4.9 Install and maintain programmable logic controllers (PLCs).
7.4.10 Explain the operation and design of various control relays
7.4.11 Identify and explain the purpose of three sections found in a PLC
7.4.12 Identify different output devices for a PLC and how they are controlled (e.g., lights, motors, solenoids etc.)
7.4.13 Identify different input devices for a PLC and how they are controlled (e.g., photoelectric, proximity, switches, push buttons, etc.)
7.4.14 Demonstrate and execute data transfers in PLC networks.

Strand 7. Computer Integrated Manufacturing

Learners apply the principles of computer integrated manufacturing related to robotics, programmable logic controllers and automated systems.

Outcome 7.5 **Automation:** Conceptualize the use of automation in manufacturing and apply this technique to a production process

Competencies:

7.5.1 Describe key concepts of automation and its importance in advanced manufacturing
7.5.2 Identify various automation tools and techniques and explain their functions (e.g., robots, sensors, controls etc)
7.5.3 Identify the PLC of an automated system and explain its importance to the cell
7.5.4 Collect data from an automated system to identify continous improvement opportunities
7.5.5 Analyze data gathered from an automated system to identify continous improvement opportunities
7.5.6 Apply continous improvement techniques to enhance the manufacturing process
7.5.7 Diagnose and troubleshoot errors within an automated system
7.5.8 Identify processes in the production that can be automated
7.5.9 Explain the function of industrial network components and adressing methods (switches, IP address, etc)
7.5.10 Configure industrial network settings (assign IP addresses, establish connectivity, interpret status indicators etc)
7.5.11 Analyze industrial network communication faults using diagnostic information (link lights, error messages, connectivity tests etc)
7.5.12 Describe industrial communication methods between automation devices (discrete signals, analog signals, serial communication etc.)
7.5.13 Interpret communication information to determine exchange status
7.5.14 Evaluate communication between automation components and correct communication issues
7.5.15 Explain the purpose and structure of ISA automation standards used in industrial systems (ISA-95 system hierarchy, ISA-88 batch control model, etc).

Strand 7. Computer Integrated Manufacturing

Learners apply the principles of computer integrated manufacturing related to robotics, programmable logic controllers and automated systems.

Outcome 7.6 **Robotic Tooling**: Classify, select, and integrate robotic tools and equipment relevant to a specific process

Competencies:

7.6.1 Classify various types of robotic tooling used in machining (e.g., end-of-arm tooling, grippers, vacuum systems, etc.).
7.6.2 Identify various types of materials used to create robotic tools and components.
7.6.3 Describe the functionality and purpose of robotic tooling in manufacturing processes.
7.6.4 Select appropriate robotic tool based on job specifications and material requirements.
7.6.5 Design custom robotic tools to meet operational and job requirements.
7.6.6 Perform setup and integration of robotic tools within manufacturing systems.
7.6.7 Evaluate the effectiveness of robotic tooling in achieving production goals.

Strand 8. Aerospace Engineering

Learners apply principles of space flight evolution, orbital mechanics, and rocketry. They gain essential knowledge and skills in understanding space missions, applying orbital mechanics, and designing and testing rockets.

Outcome 8.1 **Evolution of Space Flight:** Understand and describe the contributions, significance, and key figures of major space missions and advancements.

Competencies:

8.1.1 Describe contributions and the significance of the Mercury Missions
8.1.2 Describe contributions and the significance of the Gemini Missions
8.1.3 Describe contributions and the significance of the Apollo Missions
8.1.4 Describe contributions and the significance of the Shuttle Missions
8.1.5 Describe accomplishments and significance of space telescopes.
8.1.6 Describe accomplishments and significance of the International Space Station
8.1.7 Describe current and future astronautical advancements and their significance
8.1.8 Recall and explain the accomplishments and significance of unmanned space missions (e.g. Sputnik, Voyager, etc.)
8.1.9 Identify the pilots involved in the missions above and the significance to the evolution of space flight (e.g. Armstrong, Glenn, Yeager)

Strand 8. Aerospace Engineering

Learners apply principles of space flight evolution, orbital mechanics, and rocketry. They gain essential knowledge and skills in understanding space missions, applying orbital mechanics, and designing and testing rockets.

Outcome 8.2 Orbital Mechanics: Understand and apply orbital mechanics principles

Competencies:

8.2.1 Explain the orbital mechanics of the moon
8.2.2 Describe the conditions that must be met in order to visually identify satellites
8.2.3 Visually identify satellites and ground trace the orbital path
8.2.4 Compare and contrast different types of satellite orbital paths.
8.2.5 Identify the benefits of a telescope in space vs a telescope on Earth.
8.2.6 Describe how the earth's rotational speed determines a rocket's direction of travel during launch
8.2.7 Calculate the speed of Earth's rotation and determine the location that creates the most efficient escape velocity.
8.2.8 Define the reentry corridor for a space vehicle.
8.2.9 Describe the relationship between potential and kinetic energy for an object in orbit.
8.2.10 Describe the function of heat shields and their effect on total energy dissipation during reentry to earth's atmosphere.

Strand 8. Aerospace Engineering

Learners apply principles of space flight evolution, orbital mechanics, and rocketry. They gain essential knowledge and skills in understanding space missions, applying orbital mechanics, and designing and testing rockets.

Outcome 8.3 **Rocketry:** Design, build, and test rockets, understanding their mechanics and performance.

Competencies:

8.3.1 Describe the requirements and specifications for a launch site including safety
8.3.2 Calculate the G-Force a rocket experience during launch
8.3.3 Define terminal velocity
8.3.4 Describe Max Q and the effects on a rocket body breaking through the sound barrier
8.3.5 Describe solid, hybrid, and cryogenic liquid rocket motors.
8.3.6 Describe hypergolic fuels
8.3.7 Describe the designs of solid rocket motors and how it affects force (e.g. internal shape, nozzle)
8.3.8 Explain drag coefficient and how it affects apogee
8.3.9 Determine the directional vector a rocket will travel based on different wind conditions (weather cocking).
8.3.10 Manually identify a rocket's center of gravity and its center of pressure
8.3.11 Use a computer simulation to determine a rocket's margin of stability.
8.3.12 Explain how atmospheric conditions affect the ascent and descent rate of a rocket.
8.3.13 Calculate a vehicle's drag and descent rate during re-entry.
8.3.14 Design, build, and test a rocket

Strand 9. Technical Math and Science

Learners apply principles of space flight evolution, orbital mechanics, and rocketry. They gain essential knowledge and skills in understanding space missions, applying orbital mechanics, and designing and testing rockets.

Outcome 9.1 **Physics of Engineering:** Learn the fundamentals of physics as it relates to engineering.

Competencies:

9.1.1 Display and interpret numbers in scientific notation and logarithmic scales
9.1.2 Describe and convert SI and US system units of measurement.
9.1.3 Identify and use both metric and inch rules.
9.1.4 Express physical quantities with appropriate number of significant digits, units and dimensions.
9.1.5 Perform operations on whole numbers, fractions and mixed numbers.
9.1.6 Analyze measurements and perform technical calculations.
9.1.7 Read and interpret charts and tables to analyze data and formulate outcomes.
9.1.8 Quantitatively describe the units used in pressure measurement, such as Torr, and convert between units.
9.1.9 Quantitatively describe the units used in temperature measurement and convert between units (e.g. Fahrenheit, Celsius, Kelvin)
9.1.10 Quantitatively describe the units used in density measurement and convert between units (e.g. g/mL, g/cm3, g/L, kg/L, kg/m3)
9.1.11 Describe a non-quantitative 'mean free path'.
9.1.12 Explain how the measure of pressure relates to mean free path.
9.1.13 Describe and justify the importance of dimensional measurement.
9.1.14 Identify/differentiate engineering drawings.
9.1.15 Interpret basic schematics or diagrams, including a parts list.
9.1.16 Use facility drawings to locate equipment.
9.1.17 Compare and contrast weight vs mass
9.1.18 Explain Newton's three laws of motion and identify their relationship to a specified topic

Strand 9. Technical Math and Science

Learners apply principles of space flight evolution, orbital mechanics, and rocketry. They gain essential knowledge and skills in understanding space missions, applying orbital mechanics, and designing and testing rockets.

Outcome 9.2 **Physics of Flight:** Understand and apply the principles of flight dynamics and aerodynamics.

Competencies:

9.2.1 Describe the layers of the atmosphere
9.2.2 Explain Bernoulli's Principle and the four forces of flight; thrust, drag, lift, and weight.
9.2.3 Describe gravity and microgravity
9.2.4 Compare gravitational forces of different planets and objects.
9.2.5 Define aerodynamics and the design factors affecting flight.
9.2.6 Describe how the properties of air flow impact flight (e.g. velocity, inclination to flow, viscosity, compressibility and Reynold's number)
9.2.7 Identify the speed of sound and explain why air pressure, density and temperature affect its value
9.2.8 Compare and contrast the speed of lightning vs speed of light.
9.2.9 Calculate launch force, thrust to weight ratio and describe the relationship to specific impulse.
9.2.10 Interpret thrust curves.
9.2.11 Determine the altitude of a projectile using a clinometer.
9.2.12 Calculate the peak velocity of an object
9.2.13 Calculate projectile motion in a vacuum.
9.2.14 Define free return trajectory
9.2.15 Calculate potential, kinetic and total energy.

Strand 9. Technical Math and Science

Learners apply principles of space flight evolution, orbital mechanics, and rocketry. They gain essential knowledge and skills in understanding space missions, applying orbital mechanics, and designing and testing rockets.

Outcome 9.3 **Physics of Welding:** Apply the physics of arc welding to the process of joining metal.

Competencies:

9.3.1 Explain how the welding arc produces a weld.
9.3.2 Identify the factors that affect heat transfer.
9.3.3 Identify the factors that affect melting.
9.3.4 Describe the effects of arc length and shielding gases on the arc.
9.3.5 Identify key variables that determine the type of metal transfers.
9.3.6 Explain the characteristics of different transfer modes (i.e., short circuit, globular, spray transfer, pulsed spray transfer).
9.3.7 Describe the relationship between wire feed speed, current and voltage.
9.3.8 Describe the effects of wire size and type on deposition rate and current ranges.
9.3.9 Identify the characteristics of a stable arc, arc voltage and arc length.
9.3.10 Describe the relationship of current and voltage as it applies to constant voltage power sources.
9.3.11 Explain conditions when arc blow occurs and how to reduce arc blow.
9.3.12 Describe how polarity affects the arc welding process.
9.3.13 Explain the effects of high frequency when welding aluminum with the gas tungsten arc welding (GTAW) process.
9.3.14 Compare transformers, rectifiers and inverters in relation to the arc welding process.

Strand 9. Technical Math and Science

Learners apply principles of space flight evolution, orbital mechanics, and rocketry. They gain essential knowledge and skills in understanding space missions, applying orbital mechanics, and designing and testing rockets.

Outcome 9.4 **Measurement and Interpretation:** Interpret drawings and documentation and perform measurements.

Competencies:

9.4.1 Identify measuring tools and gradations used in precision machining and their purposes.

9.4.2 Identify typical measurements in precision machining (e.g., angles, diameter, hardness).

9.4.3 Identify measuring systems and convert between systems.

9.4.4 Identify information and symbols provided in drawings and specifications.

9.4.5 Skill in taking accurate measurements of material properties, components, and finished products using appropriate measuring tools & equipment

9.4.6 Evaluate the influence environmental factors can have on a part (e.g., temperature)

9.4.7 Ability to utilize a variety of different measuring instruments

9.4.8 Identify advanced measuring techniques and understand how they are being used to measure work pieces (Probing, Scanning etc...)

Strand 10. Maintenance, Safety and Quality

Learners apply principles of protection, prevention and mitigation to create and maintain safe working conditions at manufacturing sites. Knowledge and skills may be applied in all aspects of personal and site safety, including handling materials, using tools and equipment, working with and around electricity and using personal protective equipment.

Outcome 10.1 Site Safety: Handle materials, prevent accidents and mitigate hazards.

Competencies:

10.1.1 Knowledge of safety standards and regulations, including Hazard Communication (HAZCOM) and Occupational Safety and Health Administration (OSHA) requirements (e.g., Working at Heights, Confined Space)

10.1.2 Knowledge of risk identification, evaluation, and mitigation strategies

10.1.3 Apply inspection, rejection criteria, hitch configurations and load-handling practices to slings and rigging hardware.

10.1.4 Demonstrate proper use of American National Standards Institute (ANSI) hand signals.

10.1.5 Identify source of electrical and mechanical hazards and use shut-down and established lock out/tag-out procedures.

10.1.6 Identify and eliminate worksite clutter in accordance with standards for cleanliness and safety.

10.1.7 Identify procedures for the handling, storage and disposal of hazardous materials.

10.1.8 Identify the location of emergency equipment (eyewash fountains, Safety Data Sheets (SDSs), fire alarms, fire extinguishers, etc.) and utilize them when necessary.

10.1.9 Respond effectively to manufacturing-related emergencies and adapt response plans.

10.1.10 Identify the components of a hazardous materials safety plan.

10.1.11 Develop and implement emergency response plans and be able to conduct emergency drills and exercises.

10.1.12 Set up for ergonomic workflow.

10.1.13 Describe the interactions of incompatible substances when measuring and mixing chemicals.

10.1.14 Explain the role of third part certification (UL, IE, OSHA, etc.)

10.1.15 Apply information in the National Electrical Code (NEC) and other applicable codes when working on a job.

10.1.16 Identify safety devices and protective measures used in automated systems (emergency stops, interlocks, guarads, etc).

Strand 10. Maintenance, Safety and Quality

Learners apply principles of protection, prevention and mitigation to create and maintain safe working conditions at manufacturing sites. Knowledge and skills may be applied in all aspects of personal and site safety, including handling materials, using tools and equipment, working with and around electricity and using personal protective equipment.

Outcome 10.2 Personal Safety: Practice personal safety.

Competencies:

10.2.1 Interpret personal safety rights according to the Employee Right to Know plan.
10.2.2 Describe how working under the influence of drugs and alcohol increases the risk of accidents, lowers productivity, raises insurance costs and reduces profits.
10.2.3 Select, use, store, maintain and dispose of personal protective equipment (PPE) appropriate to job tasks, conditions and materials.
10.2.4 Identify workplace risk factors associated with lifting, operating and moving heavy objects and establish an ergonomics process.
10.2.5 Identify, inspect and use safety equipment appropriate for a task.
10.2.6 Use safe practices when working with electrical, mechanical, or other equipment.
10.2.7 Create and distribute training materials.
10.2.8 Safely operate manual, electrical-powered and pneumatic tools. insurance costs and reduces profits.
10.2.3 Select, use, store, maintain and dispose of personal protective equipment (PPE) appropriate to job tasks, conditions and materials.
10.2.4 Identify workplace risk factors associated with lifting, operating and moving heavy objects and establish an ergonomics process.
10.2.5 Identify, inspect and use safety equipment appropriate for a task.
10.2.6 Use safe practices when working with electrical, mechanical, or other equipment.
10.2.7 Create and distribute training materials.
10.2.8 Safely operate manual, electrical-powered and pneumatic tools.
10.2.9 Follow established safety procedures when working on automated equipment (apply lockout/tagout, PPE, verify energy state, etc).

Strand 10. Maintenance, Safety and Quality

Learners apply principles of protection, prevention and mitigation to create and maintain safe working conditions at manufacturing sites. Knowledge and skills may be applied in all aspects of personal and site safety, including handling materials, using tools and equipment, working with and around electricity and using personal protective equipment.

Outcome 10.3 Industrial Maintenance Safety: Plan, develop and ensure industrial maintenance safety.

Competencies:

10.3.1 Safely operate machinery and equipment.
10.3.2 Follow equipment shutdown procedures.
10.3.3 Perform leak checks on equipment.
10.3.4 Report and document unsafe machinery conditions.
10.3.5 Safely operate platforms, man lifts and ladders.
10.3.6 Identify tools and equipment requiring safety certification.
10.3.7 Use environmental data systems.
10.3.8 Monitor equipment for unsafe conditions.
10.3.9 Identify the benefits of cross-training.
10.3.10 Deliver set-up and operational procedures.
10.3.11 Demonstrate cleanroom gowning (Lab) using Standard Operating Procedures (SOP).
10.3.12 Explain the safety processes and practices of high vacuum systems.
10.3.13 Describe cleanroom requirements, purpose and maintenance.
10.3.14 De-energize pneumatic, hydraulic, and vacuum systems.

Outcome 10.4 Industrial Maintenance Installation and Repair: Inspect, maintain and repair industrial equipment.

Competencies:

10.4.1 Identify installation techniques using manuals, checklists, and regulations.
10.4.2 Identify equipment alarms.
10.4.3 Maintain inspection processes and records.
10.4.4 Calibrate and adjust manufacturing equipment.
10.4.5 Inspect and correct machine malfunctions.
10.4.6 Perform roughing pump system maintenance using a complex set of equipment specific instructions.
10.4.7 Describe costs and benefits of proactive versus reactive maintenance.
10.4.8 Describe predictive time based, and preventative maintenance schemas.

Strand 10. Maintenance, Safety and Quality

Learners apply principles of protection, prevention and mitigation to create and maintain safe working conditions at manufacturing sites. Knowledge and skills may be applied in all aspects of personal and site safety, including handling materials, using tools and equipment, working with and around electricity and using personal protective equipment.

Outcome 10.5 Machine Maintenance: Maintain tools and equipment in working condition.

Competencies:

10.5.1 Identify equipment maintenance requirements in the equipment manufacturer's documentation.

10.5.2 Identify maintenance tasks required (e.g., inspecting, grinding, sharpening, dressing, lubricating, cleaning).

10.5.3 Calibrate instruments accurately, following calibration procedures, and documenting calibration records

10.5.4 Develop a preventive maintenance schedule.

10.5.5 Monitor equipment operation based off manufactures SOP

10.5.6 Repair or replace equipment and accessories as needed.

Strand 10. Maintenance, Safety and Quality

Learners apply principles of protection, prevention and mitigation to create and maintain safe working conditions at manufacturing sites. Knowledge and skills may be applied in all aspects of personal and site safety, including handling materials, using tools and equipment, working with and around electricity and using personal protective equipment.

Outcome 10.6 Quality: Ability to ensure product quality, implement quality control measures, and continuously improve product inspection processes to meet or exceed quality requirements

Competencies:

10.6.1 Identify quality control systems (e.g., Statistical Process Control (SPC), Six Sigma, Total Quality Management (TQM), Lean Management, “Plan-Do-Check-Act” etc).
10.6.2 Troubleshoot manufacturing defects.
10.6.3 Tag and segregate non-conforming material.
10.6.4 Use statistical process control (SPC) to detect and address faults in the manufacturing process
10.6.5 Explain the basic principles and purpose of Quality Control and Quality Systems
10.6.6 Describe the seven basic tools of quality control.
10.6.7 Describe data set characteristics.
10.6.8 Describe types of variation and control charts.
10.6.9 Interpret a variety of charts and diagrams used in Statistical Process Control (SPC).
10.6.10 Predict process trends using statistical methods from a set of process data.