Mechatronics I

8554/36 weeks

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Students will learn about mechatronic systems in this introductory course. These systems are comprised of mechanical, electrical, and software systems, and typically include sensors feeding data to a computer/controller, which determines how to energize a motor/actuator. Mechatronic systems form the foundation of robotics, automation, and advanced manufacturing (such as three-dimensional [3D] printing). The rapidly evolving area of mechatronics offers a variety of career options across many technological fields. Career options may include mechatronics technician and/or engineer, mechanical technician and/or engineer, electrical technician/engineer, process-control technician and/or engineer, instrumentation technician and/or engineer, machine operators, and maintenance technicians.

Task Essentials Table

- Tasks/competencies designated by plus icons (➕) in the left-hand column(s) are essential
- Tasks/competencies designated by empty-circle icons (〇) are optional
- Tasks/competencies designated by minus icons (➖) are omitted
- Tasks marked with an asterisk (*) are sensitive.
55 Distinguish between primary and secondary processes involved in the manufacture of industrial goods into finished products.
56 Explain the history of manufacturing.
57 Explain manufacturing as a technological system that transforms raw materials into products in a central location (e.g., a factory).
58 Explain the onset of advanced manufacturing.

**Understanding Manufacturing Materials**
59 Distinguish among a wide range of materials used in manufacturing.
60 Research the major material properties: physical, mechanical, chemical, thermal, electrical/magnetic, acoustical, and optical.

**Introducing Mechatronics**
61 Define the term mechatronics.
62 Research the field of mechatronics.
63 Explore emerging trends in advanced manufacturing.
64 Identify the components of a mechatronic system and how they work together.
65 Describe the use of robots as mechatronic systems.

**Understanding Tools Used in Mechatronics**
66 Identify common hand tools.
67 Identify electrical measurement devices.
68 Demonstrate use of common machine and hand tools.
69 Demonstrate how to care for machine and hand tools.
70 Compare the use of threaded fasteners and non-threaded fasteners.
71 Explain applications for fasteners.
72 Demonstrate the use of precision measurement tools (United States customary units and metric).
73 Differentiate between U.S. customary units and metric measurement systems.
74 Use U.S. customary units and metric units.

**Introducing Mechatronics Documentation**
75 Define the differences in technique among freehand sketching, manual drafting, and computer-aided drafting (CAD).
76 Interpret written specifications for manufacturing devices and systems.

**Introducing Mechanical Systems**
77 Identify types of actuators used in mechatronic systems.
78 Identify types of sensors used in mechatronic systems.
79 Identify mechanical components within a given system or module.
80 Identify machine elements.
81 Read mechanical drawings.

**Introducing Electrical Systems**
82 Identify types of motors and/or actuators.
83 Describe the parts of the motor control system.
84 Describe the electromagnetic properties of a motor.
85 Describe the connectors.
86 Interpret line diagrams for a motor-control station.
87 Assemble a motor-control station using normally open (NO) and normally closed (NC) switches.
88 Define Ohm’s law.
89 Compute current, resistance, or voltage using Ohm’s law.
90 Define Kirchhoff’s current law (KCL) and Kirchhoff’s voltage law (KVL).
91 Compute current, voltage, and resistance in a circuit using Kirchhoff’s current law (KCL) and Kirchhoff’s voltage law (KVL).
92 Define electric power.
93 Compute electric power.
94 Measure resistance, voltage, and current.
95 Describe the concept of AC.

**Introducing Programmable Control Systems**
96 Identify the components of a programmable control system.
97 Identify programmable control systems.
Curriculum Framework

Applying Basic Safety Standards for Mechatronics

Task Number 39

Comply with federal, state, and local safety requirements.

Definition

Compliance should include

- understanding the roles of the Occupational Safety and Health Administration (OSHA), Virginia Occupational Safety and Health (VOSH) program, and the U.S. Environmental Protection Agency (EPA)
- identifying the OSHA Hazard Communication Standard (HCS)
- interpreting the information included on safety data sheets (SDS)
- describing the responsibilities of employers and employees under HCS.

Process/Skill Questions

- Where should hazardous materials be stored?
- What information can be found on an SDS?

Task Number 40

Demonstrate lockout-tagout procedures.

Definition

Demonstration should include

- identifying existing and potential energy sources
- using appropriate equipment
- following administrative procedures
- challenging and/or testing the equipment.

Process/Skill Questions

- Why are lockout-tagout procedures important?
- What administrative procedures are part of lockout-tagout? Why are those procedures in place?

Task Number 41

Maintain a safe working environment.

Definition

Maintenance should be ongoing and result in identifying potential hazards on a job site or in the lab, such as unstable or improperly installed electrical components, electrical hazards, job-site
debris, improperly stored materials, and air-quality hazards. When present, hazards must be remedied by appropriate measures in compliance with school and instructor guidelines.

Process/Skill Questions

- What are examples of job-site hazards?
- Why is it important to maintain safe work space standards on a job site?
- Why is it important to store materials and tools in their proper places?

Task Number 42

Explain safe working practices around electrical hazards.

Definition

Explanation should include

- identifying equipment used to test electrical circuits
- describing safe working conditions (e.g., grounding, using ground-fault circuit interrupters [GFCIs] and cords)
- demonstrating safe work habits.
- outlining lockout-tagout procedures.

Process/Skill Questions

- What is the definition of proximity work?
- What are safe working clearances, according to the National Electrical Code (NEC)?
- What are considered safe working conditions and safe work habits?
- What is the unseen hazard with electrical work?
- What are some common electrical workplace issues?

Task Number 43

Identify emergency first-aid procedures.

Definition

Identification should include procedures for accidents involving

- bodily fluids
- electrical injuries
- eye injuries
- hydraulic fluid injection injury
- falls
- burns.

Process/Skill Questions

- What steps should be followed in the event of an accident?
- Why is the knowledge of cardiopulmonary resuscitation (CPR) and automated external defibrillator (AED) use important in the electrical trades?
- Why is it important to be certified to administer first aid?
- What are the different degrees of electrical burns?
- What is CPR/AED?
Task Number 44
Identify the types of fires and the methods used to extinguish them.

Definition
Identification should include classifications of fires (e.g., Classes A, B, C, and D), causes and prevention of fires, types of extinguishers, and, when possible, the demonstrated use of a fire extinguisher, in accordance with government regulations and instructor guidelines.

Process/Skill Questions
- Why do fires have different classifications, and what are they?
- What is the fire triangle and the fire tetrahedron?
- What are the three things necessary to start a fire?
- Why is it important to know the classification of fire when trying to extinguish it?
- Why should extinguishers be inspected, and how often should they be inspected?
- What are the classifications of extinguishers?

Task Number 45
Demonstrate the use of a fire extinguisher.

Definition
Demonstration should include the use of the pull, aim, squeeze, sweep (PASS) method. Also, it should address safety procedures for extinguishing electrical related fires (e.g., securing the power).

Process/Skill Questions
- Why is it important to know how to use a fire extinguisher?
- When might a fire extinguisher be used?

Task Number 46
Identify personal protective equipment (PPE) requirements.

Definition
Identification should include procedures and OSHA-specified requirements for donning, wearing, and removing PPE (e.g., eye protection, respirator, hard hat, gloves, safety harness, hearing protection, safety shoes, steel-toed and/or leather boots).

Identification should also include explaining when a particular PPE is required.

Process/Skill Questions
- What are some dangerous effects of exposure, and how can one significantly prevent these effects?
- Why is wearing jewelry prohibited while in the lab or on the job site?

Task Number 47
Inspect hand and power tools to ensure safety and usability.

**Definition**

Inspection could include procedures for inspecting, wearing, and removing

- eye protection
- respirator
- hard hat
- gloves
- safety harness
- hearing protection
- safety shoes.

**Process/Skill Questions**

- What are some of the basic power tools?
- What are the proper actions to take before using a band saw?
- Why must a power tool with a three-prong plug be grounded?

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**Task Number 48**

**Demonstrate workplace ergonomics.**

**Definition**

Demonstration should include

- lifting with legs
- keeping back straight
- holding load close to the body
- getting help, if necessary.

**Process/Skill Questions**

- What are common injuries associated with improper lifting techniques?
- What can one do to prevent injury?
- How does proper positioning affect proper technique?

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**Task Number 49**

**Report injuries.**

**Definition**

Report should consist of an immediate oral statement of the job-related or non-job-related injury to the instructor or supervisor, which may be followed by a written confirmation reporting the date, extent of the injury, and circumstances of the incident.

**Process/Skill Questions**

- Why is it important to report injuries?
- What are common reporting procedures?
- Why is it important to report an injury promptly, before leaving the job site?
- What is workers' compensation?
- What are the key components of a report?
Task Number 50

Earn the construction industry OSHA 10-hour card.

Definition

Earning a construction industry OSHA 10-hour card will

- recognize that one has acquired 10 hours of safety instruction
- help teach national standards for personal safety within a lab environment
- validate safety skills to the industry
- help workers become more safety-conscious and responsible.

Process/Skill Questions

- What are the benefits of earning the construction industry OSHA 10-hour card?
- What is OSHA, and how are its standards validated?
- Why was OSHA established, and how has it evolved?

Task Number 51

Report personal, environmental, and equipment safety violations to the appropriate authority.

Definition

Report should include

- providing a verbal or written statement
- identifying the violation
- documenting the date when the incident or behavior was observed
- following the protocol for submitting the report to the instructor, supervisor, or the local OSHA inspector.

Process/Skill Questions

- What ethical considerations might be involved when reporting coworkers?
- Why is it important to follow reporting procedures?
- What is liability?

Task Number 52

Pass the safety exam.

Definition

Passing the safety exam should allow the instructor to approve the student for working with course materials and equipment.

Process/Skill Questions

- How often should one participate in safety training programs? Why?
- How does insurance affect the requirement of continuous retraining for safety?
- What is workers’ compensation?
Understanding Manufacturing

Task Number 53
Define manufacturing.

Definition
Definition should include a description of how manufacturing is used to solve problems. Definition could also include differentiating between types of manufacturing such as

- custom
- intermittent
- continuous
- flexible.

Process/Skill Questions

- What is the difference between custom, intermittent, continuous, and flexible manufacturing?
- What are common misconceptions about manufacturing?

Task Number 54
Identify the five general steps of manufacturing.

Definition
Identification should include the following steps:

- Preparation
- Processing
- Assembly
- Finishing
- Packaging and logistics

Identification could also include selecting a product and tracing its development through each of the five steps.

Process/Skill Questions

- What functions are accomplished in each step of the manufacturing process?
- Why is each step essential to the manufacturing process?
- How are technology and automation used in each step of the manufacturing process?

Task Number 55
Distinguish between primary and secondary processes involved in the manufacture of industrial goods into finished products.

Definition
Distinction should include an explanation of how different processes make use of specific manufacturing applications, such as the use of welding in assembling processes. Relate the specific operations required to implement the following secondary processes:
Casting and molding (e.g., sand casting)
Forming (e.g., metal forming)
Separating (e.g., machining)
Assembling (e.g., welding)
Direct digital and additive manufacturing (e.g., 3D printing)
Finishing (e.g., electroplating)

Process/Skill Questions

- What are some examples of products produced by additive processes or subtractive processes?
- What materials are commonly used in 3D printing?
- What equipment is used for subtractive processing?
- How can a process be a primary or a secondary process?

Task Number 56

**Explain the history of manufacturing.**

**Definition**
Explanation should include

- a summary of the evolution of manufacturing from the Industrial Age to the rise of mechanization
- a summary of automation in the manufacturing industry
- a summary of automation in the manufacturing industry to include Human-Robot Interaction (HRI)
- identification of milestones in the industry that led to today’s advanced manufacturing environments.

**Process/Skill Questions**

- What are some significant milestones in the history of manufacturing?
- How has technology changed the role of the worker in the modern manufacturing environment?
- How has the integration of technology driven the evolution of manufacturing processes (e.g. robotics, hazard exposures)?

Task Number 57

**Explain manufacturing as a technological system that transforms raw materials into products in a central location (e.g., a factory).**

**Definition**
Explanation should include

- inputs
- processes
- outputs
- open loop vs. closed loop
- goals.
Explanation should identify each element within the system and explain its role in the system; it should also differentiate between discrete and continuous manufacturing processes.

**Process/Skill Questions**

- What is the difference between discrete and continuous manufacturing processes?
- What is the difference between fixed and flexible automation?
- What are examples of open-loop and closed-loop systems?

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**Task Number 58**

**Explain the onset of advanced manufacturing.**

**Definition**

Explanation should include how the evolving field of advanced manufacturing applies information, automation, computation, software, sensing, interfacing, and networking to make traditional processes more efficient.

Explanation should also include modern materials used in manufacturing and recent discoveries in physical and biological sciences (e.g., nanotechnologies, computer numerical control [CNC] machinery).

**Process/Skill Questions**

- What is *Industry 4.0*?
- What role does data play in modern manufacturing?
- What role does automation play in modern manufacturing?
- What is the *Internet of Things* (IoT)?

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**Understanding Manufacturing Materials**

**Task Number 59**

**Distinguish among a wide range of materials used in manufacturing.**

**Definition**

Distinction should include describing materials as

- organic or inorganic
- renewable or nonrenewable
- engineering (e.g., metallic, magnetic, insulating, polymeric, ceramic, composite) or non-engineering (e.g., gases and liquids).

Distinction should also include the concept that materials science centers on the relationships among the processing, structure, properties, and performance of six major classes of materials:

- Metals
- Ceramics
- Polymers
- Composites
- Conductors, semiconductors, or insulators
- Biomaterials
- Materials for additive manufacturing
Process/Skill Questions

- What are examples of modern manufacturing materials?
- What makes a material organic vs. inorganic?
- What factors determine material selection?
- What are common alloys and exotic composites?

Task Number 60

Research the major material properties: physical, mechanical, chemical, thermal, electrical/magnetic, acoustical, and optical.

Definition

Research should include examples of the use of materials in advanced manufacturing (e.g., welding, machining, electromechanical technology) and should explain the importance of material properties to their selection and application in a production setting.

Research could also include:

- physical properties of a material
- mechanical properties' effect on the way a material will react to forces or loads
- natural elements' reaction with a material and its effect on performance
- thermal properties of a material (e.g., thermal resistance, thermal expansion, thermal emission, thermal shock resistance)
- materials that carry an electrical current (e.g., conductors, semiconductors, resistors)
- properties that determine how a material reacts to sound waves (e.g., acoustical transmission, acoustical reflection)
- optical properties (e.g., color, light transmission, light reflection).

Process/Skill Questions

- What properties are important when selecting a material?
- How do properties change as materials are processed?
- What processes are used to enhance final material properties?

Introducing Mechatronics

Task Number 61

Define the term mechatronics.

Definition

Definition should state that mechatronics is the implementation of mechanical, electronic, computer, and control systems working together to increase productivity, efficiency, and quality in the manufacturing of materials.

Definition should consider the concept that mechatronics, as well as its applications to everything from product design to advanced manufacturing applications, is evolving.

Process/Skill Questions

- What key components are required for a mechatronic system?
- What are examples of mechatronic systems?
• How do mechatronic systems affect society?
• What are mechatronics education pathways?

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**Task Number 62**

**Research the field of mechatronics.**

**Definition**

Research should include

• an overview of the field
• its role in advanced manufacturing
• relevant skills to be successful in the field
• current demand for mechatronics professionals.

**Process/Skill Questions**

• What is the origin of the term *mechatronics*?
• What employment opportunities exist in mechatronics?
• How is mechatronics different from traditional technical disciplines?

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**Task Number 63**

**Explore emerging trends in advanced manufacturing.**

**Definition**

Exploration should include the

• change in the types of skills needed in manufacturing
• use of computers
• use of advanced materials and machinery.

**Process/Skill Questions**

• What skills are necessary in mechatronics?
• What are process controllers and microcontrollers?
• How are computers used in advanced manufacturing?

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**Task Number 64**

**Identify the components of a mechatronic system and how they work together.**

**Definition**

Identification should include how the following essential components work together

• actuators
• sensors
• control devices.

The following components may also be included:
• Graphic displays
• Power sources
• Communication protocols (e.g., Transmission Control Protocol/Internet Protocol [TCP/IP], controller area network [CAN])

Process/Skill Questions

• How are the required components of a mechatronic system described?
• What makes a system a mechatronics system?
• What is the difference between mechatronics and automation?

Task Number 65
Describe the use of robots as mechatronic systems.

Definition
Description should include feedback mechanisms as well as applications of robotic systems within various industries.

Process/Skill Questions

• Why would a robot be considered a mechatronic system?
• How are robots used in industry?
• How are robots replacing human workers?

Understanding Tools Used in Mechatronics

Task Number 66
Identify common hand tools.

Definition
Identification may include

• clamping devices
• pliers
• wrenches
• torque wrenches
• screwdrivers
• chisels
• saws and cutting tools
• reamers
• hand taps
• dies
• soldering and desoldering iron and gun
• wire cutters and strippers
• connectors.

Process/Skill Questions

• What are the purposes of different types of pliers?
• What tools are used in the mechatronics field?
• What is the importance of a torque wrench?
Task Number 67
Identify electrical measurement devices.
Definition
Identification should include
- digital multimeter (alternating current/direct current [AC/DC])
- oscilloscope
- function generator.

Process/Skill Questions
- How does a digital multimeter work?
- What is the purpose of a function generator?

Task Number 68
Demonstrate use of common machine and hand tools.
Definition
Demonstration should comply with instructor guidelines for safe use.

Process/Skill Questions
- What injuries are common with simple hand tools?
- What are proper techniques for using machine and hand tools?

Task Number 69
Demonstrate how to care for machine and hand tools.
Definition
Demonstration should include
- storage and/or organization
- lubrication.

Process/Skill Questions
- Why is the care of machine and hand tools important?
- What hazards exist when maintaining machine tools and hand tools (e.g. SDS warnings)?

Task Number 70
Compare the use of threaded fasteners and non-threaded fasteners.
Definition
Comparison could include identifying various types of fasteners, such as
- bolts and screws
- nuts
• anchors
• rivets
• cotter pins
• retaining rings.

Comparison could also include

• grades of bolts
• identification systems (e.g., Unified National Coarse/Unified National Fine/National Pipe Taper [UNC/UNF/NPT]).

Process/Skill Questions

• What factors help determine which fastener to use for a specific application?
• How are fasteners classified and identified?
• How can fasteners which create friction be differentiated from those that do not?

Task Number 71

Explain applications for fasteners.

Definition

Explanation should include the use of fasteners when

• mounting
• connecting
• assembling

mechatronic equipment or hardware.

Process/Skill Questions

• What dimensional factors should be considered when selecting a fastener?
• What must be considered when selecting fastener materials (e.g. material incompatibilities, corrosion)?

Task Number 72

Demonstrate the use of precision measurement tools (United States customary units and metric).

Definition

Demonstration could include use of

• levels
• scales
• feeler gauges
• thread pitch gauges
• calipers (Vernier or dial)
• micrometers
• dial indicators
• protractors
• parallels and gauge blocks
• precision straightedges
• rulers.

Process/Skill Questions

• What is the difference between the U.S. customary and metric systems? Provide an example of each.
• Why is precision measurement important and how is the right tool selected?
• How should precision measurement tools be handled?

Task Number 73
Differentiate between U.S. customary units and metric measurement systems.

Definition
Differentiation should include unit conversion, nomenclature, and standard notations in each measurement system.

Process/Skill Questions

• What are the standards for screw threads?
• What are common abbreviations for units?
• What do unit prefixes mean?

Task Number 74
Use U.S. customary units and metric units.

Definition
Use should include

• conversions
• nomenclature
• standard notations.

Use should also include tools specific to each system (e.g., scale, ruler).

Process/Skill Questions

• How are different unit standards converted?
• What tools should be used for various measurement applications?

Introducing Mechatronics Documentation

Task Number 75
Define the differences in technique among freehand sketching, manual drafting, and computer-aided drafting (CAD).

Definition
Definition of the differences in technique should include a description of the skills required for freehand sketching, manual drafting, and CAD.
Process/Skill Questions

• Why is each drawing technique important?
• What advantages has CAD modeling provided (e.g., sharing, accuracy, speed, computer-assisted manufacturing [CAM], 3D printing)?

Task Number 76
Interpret written specifications for manufacturing devices and systems.

Definition
Interpretation may include

• lab procedures
• owner’s manual
• safety data sheets (SDS)
• part numbers
• dimensions.

Process/Skill Questions

• What information can be found in SDS?
• Why is knowing dimensions for system components beneficial?
• Why are clearly written specifications and instructions important?

Introducing Mechanical Systems

Task Number 77
Identify types of actuators used in mechatronic systems.

Definition
Identification should include

• electromechanical
• pneumatic
• hydraulic.

Process/Skill Questions

• What is an actuator?
• What factors influence the type of actuator chosen for a specific application?
• What common types of actuators are used in a mechatronic system?

Task Number 78
Identify types of sensors used in mechatronic systems.

Definition
Identification should include sensors that measure

• switches
- temperature
- force
- speed
- pressure
- flow rate
- proximity
- magnetism
- light.

**Process/Skill Questions**

- What are common types of sensors used in mechatronic systems?
- What physical properties do sensors detect?
- What is the importance of a sensor in a mechatronic system?
- What is the difference between an analog and a digital sensor?

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**Task Number 79**

**Identify mechanical components within a given system or module.**

**Definition**
Identification should include

- levers
- gear drives
- belt drives
- chain drives
- lead screws(ball screws).

**Process/Skill Questions**

- In what products can these components be found?
- What are different types of gears and what is the specific use of each?

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**Task Number 80**

**Identify machine elements.**

**Definition**
Identification should include elements such as

- fasteners
- bearings
- couplings
- gears
- shafts
- springs
- sheaves
- sprockets
- shims.
Process/Skill Questions

- What is the importance of lubricating machine elements?
- What forces would each component experience (e.g. axial, radial, torque)?
- What is the difference between a gear and a sprocket?

Task Number 81
Read mechanical drawings.

Definition
Reading mechanical drawings should include interpretation.

Process/Skill Questions

- What standards are used in the United States for mechanical drawings?
- What are the benefits of having accurate mechanical drawings?

Introducing Electrical Systems

Task Number 82
Identify types of motors and/or actuators.

Definition
Identification should include

- electrical (AC/DC)
- pneumatic
- hydraulic.

Process/Skill Questions

- What is the difference between AC and DC motors?
- What is the difference between pneumatic and hydraulic motors?

Task Number 83
Describe the parts of the motor control system.

Definition
Description should include

- motor starters
- overload
- contactor/relay
- switches
- timers
- variable frequency drives.

Process/Skill Questions

- What are the three main parts of a mechatronic system?
- What is the main function of a contact/relay?
• How is an overload selected for a given application?

Task Number 84
Describe the electromagnetic properties of a motor.

Definition
Description could include

• voltage
• current
• power
• motor curve
• torque/revolutions per minute (RPM).

Process/Skill Questions

• What causes the rotor to turn in an electrical motor or generator?
• What are the main differences between AC and DC motors?
• How does the stepper motor work?

Task Number 85
Describe the connectors.

Definition
Description could include

• Plug-and-socket connectors
• jacks and plugs
• crimp-on connectors
• soldered connectors
• insulation-displacement connectors
• binding posts
• screw terminals
• ring-and-spade connectors
• blade connectors
• other connection methods.

Process/Skill Questions

• What are the main types of connectors used for electrical connections?
• How are connectors sized for different applications?

Task Number 86
Interpret line diagrams for a motor-control station.

Definition
Interpretation should include

• symbols
• line numbers
• wire numbers
• reference numbers.

**Process/Skill Questions**

• What is the symbol for a relay in a line diagram?
• Why do we need line or wire numbers in a line diagram?
• How is the normal condition of a diagram shown as compared to the actuated condition?

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**Task Number 87**

**Assemble a motor-control station using normally open (NO) and normally closed (NC) switches.**

**Definition**

Assembly should include using contactors to wire the following switches:

• Single start/stop
• Multiple start/stop
• Start/stop/jog
• Sequential start/stop
• Safety start
• Forward/reverse.

**Process/Skill Questions**

• What is the difference in using NO vs. NC switches?
• How is each assembly similar and different?

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**Task Number 88**

**Define Ohm’s law.**

**Definition**

Definition should include

• providing the equation of Ohm’s law: voltage (E) is equal to current (I) multiplied by resistance (R)
• describing Ohm’s law as a simple and useful tool for analyzing electric circuits
• description of non-Ohmic materials (e.g., diodes, transistors).

**Process/Skill Questions**

• What are the ways that voltage is identified and is it always the same?
• What are the relationships between voltage, current, and resistance?
• How is Ohm’s law useful?
• What are some of the limitations of Ohm’s law?

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**Task Number 89**

**Compute current, resistance, or voltage using Ohm’s law.**
Definition
Computation requires an understanding of the mathematical and scientific concepts related to Ohm’s law and should include defining the terms of the equation for Ohm’s law: \( E = IR; \ I = \frac{E}{R}; \ R = \frac{E}{I} \).

Process/Skill Questions
- What is the relationship of current to resistance if the voltage is held constant in a DC circuit?
- What are the base units of voltage, current, and resistance in Ohm’s law?
- What is the value of \( R \) in the equation if the circuit has a 1.7 kΩ resistor?

Task Number 90
Define Kirchhoff’s current law (KCL) and Kirchhoff’s voltage law (KVL).

Definition
Definition should include
- a description of current flowing into a node and current flowing out of a node
- a description of voltage sources and voltage drops in a circuit loop.

Process/Skill Questions
- What is a node in a circuit?
- What could be considered a voltage source in a circuit?
- What could be considered a voltage drop in a circuit?

Task Number 91
Compute current, voltage, and resistance in a circuit using Kirchhoff’s current law (KCL) and Kirchhoff’s voltage law (KVL).

Definition
Computation should include
- the sum of all currents flowing into a node equals the sum of all current flowing out of a node
- the sum of all voltage sources in a circuit loop equals the sum of all voltage drops in a circuit.

Process/Skill Questions
- How does one assign the direction of current flow into or out of a node?
- What does a negative current value indicate?
- What notation is used to indicate a voltage source vs. a voltage drop?

Task Number 92
Define electric power.
Definition
Definition should include a description of how voltage, current, and resistance relate to electrical power, measured in watts (W).

Process/Skill Questions
- What are some examples of appliances and their power consumption?
- What is a kilowatt (kW)?

Task Number 93
Compute electric power.

Definition
Computation should include
- the basic form of the equation, relating the product of voltage and current to power
- the other forms of the equation, incorporating Ohm’s Law, to relate resistance to power.

Process/Skill Questions
- How is electrical power affected by an increase in voltage, current, or resistance?
- When the resultant power is very large, how is it commonly notated?

Task Number 94
Measure resistance, voltage, and current.

Definition
Measurement should include checking resistance, voltage, and current and finding the value of each using a digital multimeter.

Process/Skill Questions
- Why does a digital multimeter have different scales for measuring resistance?
- What precautions must be taken when measuring current in a circuit?
- How does the tolerance of a resistor affect the value?

Task Number 95
Describe the concept of AC.

Definition
Description should include
- how voltage and current varies as time passes
- the difference between single phase and three phase
- root mean square (RMS) vs. peak voltage.

Process/Skill Questions
- Why is AC used to distribute most of the utility power in the world?
- How fast does the voltage fluctuate? How does that vary from the U.S. to other places in the world?
- Where would a three-phase power be found?

**Introducing Programmable Control Systems**

**Task Number 96**

**Identify the components of a programmable control system.**

**Definition**

Identification should include

- central processing unit (CPU)
- integrated development environment (IDE)
- input/output modules
- power supply.

**Process/Skill Questions**

- What are examples of a programmable controller?
- What are examples of the languages through which programmable control systems are programmed?
- What manufacturing processes can be controlled by a programmable control system?

**Task Number 97**

**Identify programmable control systems.**

**Definition**

Identification should include

- programmable logic controller/programmable automation controller (PLC/PAC)
- personal computer (PC)-based controllers
- microcontrollers.

**Process/Skill Questions**

- What is the main difference between a PLC and PAC?
- What are the main advantages of using PLCs in environments with high electrical noise, vibrations, and impact?

**SOL Correlations by Task**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>English: 10.5, 11.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comply with federal, state, and local safety requirements.</td>
<td>Science: CH.1</td>
</tr>
<tr>
<td></td>
<td>History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9</td>
</tr>
<tr>
<td>Demonstrate lockout-tagout procedures.</td>
<td></td>
</tr>
<tr>
<td>Maintain a safe working environment.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td><strong>Activity</strong></td>
<td><strong>Resource</strong></td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
<td>--------------------------------------------------</td>
</tr>
</tbody>
</table>
| Explain safe working practices around electrical hazards.                  | English: 10.3, 10.5, 10.6, 10.7, 11.3, 11.5, 11.6, 11.7  
History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Identify emergency first-aid procedures.                                   | English: 10.5, 11.5  
WHII 8; VUS 8; Govt 7, 8, 9 |
| Identify the types of fires and the methods used to extinguish them.        | English: 10.5, 11.5  
Science: CH.1  
History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Demonstrate the use of a fire extinguisher.                                | History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Identify personal protective equipment (PPE) requirements.                 | English: 10.5, 11.5  
History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Inspect hand and power tools to ensure safety and usability.               | English: 10.5, 11.5  
History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Demonstrate workplace ergonomics.                                          | History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Report injuries.                                                           | English: 10.5, 10.6, 10.7, 11.5, 11.6, 11.7  
History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Earn the construction industry OSHA 10-hour card.                          | English: 10.5, 11.5  
History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Report personal, environmental, and equipment safety violations to the appropriate authority. | English: 10.5, 10.6, 10.7, 11.5, 11.6, 11.7  
History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Pass the safety exam.                                                       | English: 10.5, 11.5  
History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Define manufacturing.                                                      | English: 10.3, 10.5, 11.3, 11.5  
History and Social Sciences: WHII 8; VUS 8; Govt 7, 8, 9 |
| Identify the five general steps of manufacturing.                          | English: 10.5, 11.5 |
| Distinguish between primary and secondary processes involved in the manufacture of industrial goods into finished products. | English: 10.5, 11.5 |
| Explain the history of manufacturing.                                       | English: 10.5, 11.5  
History and Social Sciences: WHII 8, 14; VUS 8, 14; Govt 7, 8, 9 |
| Explain manufacturing as a technological system that transforms raw materials into products in a central location (e.g., a factory). | English: 10.5, 11.5  
History and Social Sciences: WHII 8, 14; VUS 8, 14; Govt 7, 8, 9 |
| Explain the onset of advanced manufacturing.                               | English: 10.5, 11.5  
History and Social Sciences: WHII 8, 14; VUS 8, 14; Govt 7, 8, 9 |
| Distinguish among a wide range of materials used in manufacturing.         | English: 10.5, 11.5  
Science: CH.6 |
<table>
<thead>
<tr>
<th>Subject</th>
<th>Course/Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research the major material properties:</td>
<td>WHII 8, 14; VUS 8, 14; Govt 7, 8, 9</td>
</tr>
<tr>
<td>physical, mechanical, chemical, thermal,</td>
<td>English: 10.5, 10.8, 11.5, 11.8</td>
</tr>
<tr>
<td>electrical/magnetic, acoustical, and optical.</td>
<td>Science: PH.7</td>
</tr>
<tr>
<td>Define the term mechatronics.</td>
<td>English: 10.3, 10.5, 11.3, 11.5</td>
</tr>
<tr>
<td>Research the field of mechatronics.</td>
<td>English: 10.5, 10.8, 11.5, 11.8</td>
</tr>
<tr>
<td>Identify the components of a mechatronic system and how they work together.</td>
<td>History and Social Sciences: WHII 8, 14; VUS 8, 14; Govt 7, 8, 9</td>
</tr>
<tr>
<td>Describe the use of robots as mechatronic systems.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Identify common hand tools.</td>
<td>History and Social Sciences: WHII 8, 14; VUS 8, 14; Govt 7, 8, 9</td>
</tr>
<tr>
<td>Identify electrical measurement devices.</td>
<td></td>
</tr>
<tr>
<td>Demonstrate use of common machine and hand tools.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Demonstrate how to care for machine and hand tools.</td>
<td></td>
</tr>
<tr>
<td>Compare the use of threaded fasteners and non-threaded fasteners.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Explain applications for fasteners.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Demonstrate the use of precision measurement tools (United States customary units and metric).</td>
<td></td>
</tr>
<tr>
<td>Differentiate between U.S. customary units and metric measurement systems.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Use U.S. customary units and metric units.</td>
<td>Science: CH.1</td>
</tr>
<tr>
<td>Define the differences in technique among freehand sketching, manual drafting, and computer-aided drafting (CAD).</td>
<td>English: 10.3, 10.5, 11.3, 11.5</td>
</tr>
<tr>
<td>Interpret written specifications for manufacturing devices and systems.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Identify types of actuators used in mechatronic systems.</td>
<td>Science: CH.1</td>
</tr>
<tr>
<td>Identify types of sensors used in mechatronic systems.</td>
<td></td>
</tr>
<tr>
<td>Identify mechanical components within a given system or module.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Identify machine elements.</td>
<td></td>
</tr>
<tr>
<td>Read mechanical drawings.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Identify types of motors and/or actuators.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Describe the parts of the motor control system.</td>
<td>Science: PH.11</td>
</tr>
<tr>
<td>Describe the electromagnetic properties of a motor.</td>
<td></td>
</tr>
<tr>
<td>Describe the connectors.</td>
<td></td>
</tr>
<tr>
<td>Task</td>
<td>English: 10.3, 10.5, 11.3, 11.5</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Interpret line diagrams for a motor-control station.</td>
<td></td>
</tr>
<tr>
<td>Assemble a motor-control station using normally open (NO) and normally closed (NC) switches.</td>
<td></td>
</tr>
<tr>
<td>Define Ohm’s law.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Compute current, resistance, or voltage using Ohm’s law.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Define Kirchhoff’s current law (KCL) and Kirchhoff’s voltage law (KVL).</td>
<td>English: 10.3, 10.5, 11.3, 11.5</td>
</tr>
<tr>
<td>Compute current, voltage, and resistance in a circuit using Kirchhoff’s current law (KCL) and Kirchhoff’s voltage law (KVL).</td>
<td>Mathematics: A.1, A.4a,c</td>
</tr>
<tr>
<td>Define electric power.</td>
<td>English: 10.3, 10.5, 11.3, 11.5</td>
</tr>
<tr>
<td>Compute electric power.</td>
<td>Mathematics: A.4c, A.8, AII.3c</td>
</tr>
<tr>
<td>Measure resistance, voltage, and current.</td>
<td>Science: PH.11</td>
</tr>
<tr>
<td>Describe the concept of AC.</td>
<td>English: 10.5, 11.5</td>
</tr>
<tr>
<td>Identify the components of a programmable control system.</td>
<td>English: 10.2, 10.5, 11.2, 11.5</td>
</tr>
<tr>
<td>Identify programmable control systems.</td>
<td>English: 10.2, 10.5, 11.2, 11.5</td>
</tr>
</tbody>
</table>

**Teacher Resources**

**Mechatronics I/II/III Teacher Resources**

- All About Circuits: Educational Resources
- Amatrol curriculum
- ASME Resources: [Mechatronics and the role of engineers](#)
- ASTM Fastener Standards
- Hand Tools and Safety
- Hydraulic Injection Injuries
- IEEE Educational Resources
- NOCTI Job Ready Assessment Blueprint: Mechatronics Level I

Penn State University Lockout/Tagout Policy:
• Overview
• Resources

SkillsUSA Resources:

• Mechatronics Contest Standard
• Mechatronics Contest Rules

Try Engineering: Differentiating between Mechatronics and Robotics
Appendix: Credentials, Course Sequences, and Career Cluster Information

Industry Credentials (Only apply to 36-week courses)

- Automated Manufacturing Technology Examination
- College and Work Readiness Assessment (CWRA+)
- Festo NC3 Introduction to Mechatronics STEM Lab Certification
- Festo NC3 Level 1 Fundamentals Certifications
- Manufacturing Specialist Certification Examination
- Manufacturing Technician Level 1 Certification Examination
- Manufacturing Technology Assessment
- Mechatronic Systems Certification Examinations
- Mechatronics Level 1 Assessment
- National Career Readiness Certificate Assessment
- Pre-Manufacturing Technician I (PreMT1) Examination
- Robotics Certification Examinations
- Workplace Readiness Skills for the Commonwealth Examination

Concentration sequences: A combination of this course and those below, equivalent to two 36-week courses, is a concentration sequence. Students wishing to complete a specialization may take additional courses based on their career pathways. A program completer is a student who has met the requirements for a CTE concentration sequence and all other requirements for high school graduation or an approved alternative education program.

- Mechatronics II (8555/36 weeks)

### Career Cluster: Manufacturing

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Occupations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Production</td>
<td>Electro-Mechanical Technician</td>
</tr>
<tr>
<td>Process Development</td>
<td>Industrial Engineer</td>
</tr>
<tr>
<td></td>
<td>Industrial Engineering Technician</td>
</tr>
<tr>
<td></td>
<td>Manufacturing Systems Engineer</td>
</tr>
<tr>
<td>Production</td>
<td>Automated Manufacturing Technician</td>
</tr>
</tbody>
</table>

### Career Cluster: Science, Technology, Engineering and Mathematics

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Occupations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering and Technology</td>
<td>Electrical Engineering Technician</td>
</tr>
<tr>
<td></td>
<td>Electro-Mechanical Technician</td>
</tr>
<tr>
<td></td>
<td>Mechanical Engineer</td>
</tr>
<tr>
<td></td>
<td>Mechanical Engineering Technician</td>
</tr>
</tbody>
</table>