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| OSHA Basic Safety | 1. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>2. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>3. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>4. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>5. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>6. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>7. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 1. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>2. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>3. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>4. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>5. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>6. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>7. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs.<br>- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.<br>- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.<br><br>8. Accessory Power (DC–DC) |

- Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

9. Accessory Motors
   - Explain the need for motor-driven accessories and identify examples in ZEBs.
   - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

10. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

11. Charging Systems
    - Plug-in (Conductive)
      i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
      ii. Identify relevant SAE standards and typical charging times.
      iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
      i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
      ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
      i. Define inductive charging.
      ii. Describe typical charging times.
      iii. Explain advantages and disadvantages.
      iv. Identify SAE standard J-2954/2.

12. Data Communication Networks
    - Describe controller area network (CAN) protocols and standards.
    - Identify CAN components:
      i. Explain terminating resistors.
      ii. Explain gateways.
      iii. Explain shielding on data cables.
    - Identify subsystems using CAN communication.
    - Explain J1939 and data acquisition methods.
    - Compare SAE, IEEE, and proprietary data.
    - Explain communication between the charger and the bus.

13. Multiplexing (MUX)
    - Describe multiplexing protocols and standards.
    - Identify MUX network components.
    - Identify subsystems using MUX communication.
    - Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

14. Telematics
    - Describe vehicle telemetry system operation.
    - Explain the function of gateways.
    - Explain shielding on data cables.
    - Explain communication with the vehicle’s 12/24 V system through multiplexing.

15. Hydrogen Fuel Cell Bus Overview
    - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).
    - Describe HFCB operation and fuel cell function.
    - Define major subsystems unique to HFCBs:
      i. Hydrogen system
      ii. Air intake system
      iii. Exhaust system

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| | iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>7. Apply safety practices when using meters.<br>8. Perform Live-Dead-Live testing on zero-emission vehicles.<br>9. Compare automotive multimeters' features and functions in practical applications.<br>10. Implement recommended practices for high-voltage measurement tools and techniques.<br>11. Diagnose and repair electrical faults effectively.<br>12. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>13. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 1. Identify electrical hazards and understand the potential injuries they can cause.<br>2. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>3. Recognize visual cues that indicate hazardous voltage presence.<br>4. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>5. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>6. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>7. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>8. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 1. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>2. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>3. Differentiate between various vehicle safety systems utilized in ZEBs.<br>4. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>5. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>6. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>7. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>8. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>9. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>10. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 1. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>2. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>3. Workplace Safety Regulations: |

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| | - Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>4. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>5. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>6. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>7. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>8. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>9. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 1. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>2. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>3. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>4. Explain thermal runaway and its possible consequences in high voltage systems.<br>5. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>6. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>7. Outline emergency towing and extraction procedures, including securement points.<br>8. Identify components necessary for high voltage isolation.<br>9. Locate passenger emergency egress areas on BEBs and HFCBs.<br>10. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>11. Explain post-incident isolation procedures for high voltage systems.<br>12. Outline basic accident and incident protocols for key personnel.<br>13. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>14. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>15. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 1. Understand the purpose and significance of Contact Release in high-voltage environments.<br>2. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>3. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>4. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>5. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>6. Demonstrate the practical skills required to perform a Contact Release.<br>7. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |

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| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 1. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>2. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 1. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>2. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>3. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>4. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>5. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>6. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>7. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 1. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>2. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>3. Apply the four steps of troubleshooting to systematically resolve issues.<br>4. Conduct root cause analysis to identify underlying problems.<br>5. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>6. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>7. Master logic and elimination methods in diagnosing vehicle issues.<br>8. Explore and assess vehicle subsystems and their potential failures.<br>9. Diagnose component failures through systematic testing and analysis. |

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| | 10. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>11. Conduct thorough component and electrical testing to confirm failures.<br>12. Measure performance to ensure effective diagnostics.<br>13. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>14. Identify and analyze software components and potential issues.<br>15. Analyze logs and fault data to inform troubleshooting processes.<br>16. Tackle complex and uncommon technical issues effectively.<br>17. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 1. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>2. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>3. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>4. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>5. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 1. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>2. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>3. High-Voltage Junction Box (HVJB) |

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| | - Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>4. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>5. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>6. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>7. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>8. Thermal Management<br>- Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>9. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.<br>- Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>10. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>11. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>12. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>13. Data Communication Networks |

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| | - Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>14. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>15. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>16. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 1. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>2. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights.<br><br>3. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>4. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>5. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs. |

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| | - Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>6. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.<br>- Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>7. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>8. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>9. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 1. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>2. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>3. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>4. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>5. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>6. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>7. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>8. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>9. Troubleshooting Techniques: |

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| | - Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>10. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>11. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |
| OSHA Basic Safety | 8. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>9. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>10. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>11. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>12. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>13. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>14. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
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22. Power Electronics
    - Understand AC/DC characteristics and advantages of AC power in ZEBs.
    - Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.
    - Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.

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    - Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

24. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

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    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

26. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.
        ii. Describe typical charging times.
        iii. Explain advantages and disadvantages.
        iv. Identify SAE standard J-2954/2.

27. Data Communication Networks
    - Describe controller area network (CAN) protocols and standards.
    - Identify CAN components:
        i. Explain terminating resistors.
        ii. Explain gateways.
        iii. Explain shielding on data cables.
    - Identify subsystems using CAN communication.
    - Explain J1939 and data acquisition methods.
    - Compare SAE, IEEE, and proprietary data.
    - Explain communication between the charger and the bus.

28. Multiplexing (MUX)
    - Describe multiplexing protocols and standards.
    - Identify MUX network components.
    - Identify subsystems using MUX communication.
    - Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

29. Telematics
    - Describe vehicle telemetry system operation.
    - Explain the function of gateways.
    - Explain shielding on data cables.

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| | - Explain communication with the vehicle's 12/24 V system through multiplexing.<br><br>30. Hydrogen Fuel Cell Bus Overview<br>- Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Describe HFCB operation and fuel cell function.<br>- Define major subsystems unique to HFCBs:<br>i. Hydrogen system<br>ii. Air intake system<br>iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>14. Apply safety practices when using meters.<br>15. Perform Live-Dead-Live testing on zero-emission vehicles.<br>16. Compare automotive multimeters' features and functions in practical applications.<br>17. Implement recommended practices for high-voltage measurement tools and techniques.<br>18. Diagnose and repair electrical faults effectively.<br>19. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>20. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 9. Identify electrical hazards and understand the potential injuries they can cause.<br>10. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>11. Recognize visual cues that indicate hazardous voltage presence.<br>12. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>13. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>14. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>15. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>16. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 11. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>12. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>13. Differentiate between various vehicle safety systems utilized in ZEBs.<br>14. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>15. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>16. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>17. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>18. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>19. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>20. Describe the ratings of PPE and their specific applications in high-voltage tasks. |

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| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 10. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>11. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>12. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>13. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>14. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>15. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>16. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>17. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>18. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 16. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>17. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>18. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>19. Explain thermal runaway and its possible consequences in high voltage systems.<br>20. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>21. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>22. Outline emergency towing and extraction procedures, including securement points.<br>23. Identify components necessary for high voltage isolation.<br>24. Locate passenger emergency egress areas on BEBs and HFCBs.<br>25. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>26. Explain post-incident isolation procedures for high voltage systems.<br>27. Outline basic accident and incident protocols for key personnel.<br>28. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses. |

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| | 29. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>30. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 8. Understand the purpose and significance of Contact Release in high-voltage environments.<br>9. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>10. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>11. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>12. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>13. Demonstrate the practical skills required to perform a Contact Release.<br>14. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 3. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>4. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 8. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>9. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>10. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>11. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>12. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>13. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement). |

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| | - Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>14. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 18. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>19. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>20. Apply the four steps of troubleshooting to systematically resolve issues.<br>21. Conduct root cause analysis to identify underlying problems.<br>22. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>23. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>24. Master logic and elimination methods in diagnosing vehicle issues.<br>25. Explore and assess vehicle subsystems and their potential failures.<br>26. Diagnose component failures through systematic testing and analysis.<br>27. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>28. Conduct thorough component and electrical testing to confirm failures.<br>29. Measure performance to ensure effective diagnostics.<br>30. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>31. Identify and analyze software components and potential issues.<br>32. Analyze logs and fault data to inform troubleshooting processes.<br>33. Tackle complex and uncommon technical issues effectively.<br>34. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 6. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>7. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>8. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>9. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>10. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity. |

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| | - Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 17. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>18. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>19. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>20. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>21. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>22. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>23. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>24. Thermal Management |

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| | - Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>25. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.<br>- Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>26. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>27. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>28. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>29. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>30. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>31. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>32. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 10. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>11. Maintenance Inspection Procedures: |

- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.
- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.
- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.
- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.
- Analyze historical telemetry data for performance insights.

12. Power Inverter/Power Electronics:
    - Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.
    - Troubleshoot power inverter faults in accordance with OEM standards.
    - Measure, interpret, and record power inverter resistance values.
    - Program inverters where applicable and diagnose the need for reprogramming or replacement.

13. Energy Storage Systems (ESS):
    - Follow OEM guidelines for the removal and replacement (R&R) of ESS components.
    - Safely troubleshoot ESS faults in accordance with OEM protocols.
    - Identify and repair ESS thermal management system faults.
    - Diagnose control system faults, including contactors and pre-charge resistors.
    - Perform battery balancing and string equalization using proper procedures.

14. Power Generation/Charging:
    - Adhere to OEM guidelines for R&R of power generation and charging components.
    - Troubleshoot power generation and charging faults according to OEM standards.
    - Inspect and repair all charging interfaces for damage or faults.
    - Differentiate between charger and bus-related faults and perform necessary repairs.
    - Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.
    - Test insulation resistance and determine deviations, repairing as needed.
    - Assess isolation resistance values, identify discrepancies, and implement repairs.

15. High-Voltage Cables:
    - Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.
    - Troubleshoot high-voltage cable and bus bar faults according to OEM standards.
    - Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.
    - Build or repair high-voltage cables, including stripping insulation and crimping lugs.

16. Traction Motors:
    - Understand and apply OEM guidelines for the repair and replacement of traction motor components.
    - Troubleshoot traction motor faults in accordance with OEM standards.
    - Conduct insulation and winding resistance tests on each motor phase.

17. Data Communication Networks:
    - Execute repair and replacement of data communication network components following OEM guidelines.
    - Troubleshoot faults within data communication networks based on OEM protocols.
    - Analyze and assess CAN network messages and integrity.
    - Utilize an oscilloscope to identify noise on the CAN bus network.
    - Analyze and graph live data, or interpret recent trace file data.
    - Perform root cause analysis of ZEB subsystems using fault data.

18. Control Systems:
    - Implement OEM guidelines for repairing and replacing control system components.
    - Diagnose control system faults in line with OEM troubleshooting procedures.
    - Interpret OEM schematics to identify control system faults.

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| | - Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 12. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>13. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>14. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>15. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>16. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>17. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>18. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>19. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>20. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>21. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>22. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |

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| OSHA Basic Safety | 15. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>16. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>17. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>18. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>19. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>20. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>21. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 31. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>32. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>33. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>34. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>35. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>36. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>37. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs.<br>- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.<br>- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.<br><br>38. Accessory Power (DC–DC) |

- Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

39. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

40. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

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    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
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        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
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    - Inductive Charging
        i. Define inductive charging.
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        iii. Explain advantages and disadvantages.
        iv. Identify SAE standard J-2954/2.

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    - Describe controller area network (CAN) protocols and standards.
    - Identify CAN components:
        i. Explain terminating resistors.
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        iii. Explain shielding on data cables.
    - Identify subsystems using CAN communication.
    - Explain J1939 and data acquisition methods.
    - Compare SAE, IEEE, and proprietary data.
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    - Describe multiplexing protocols and standards.
    - Identify MUX network components.
    - Identify subsystems using MUX communication.
    - Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

44. Telematics
    - Describe vehicle telemetry system operation.
    - Explain the function of gateways.
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    - Explain communication with the vehicle’s 12/24 V system through multiplexing.

45. Hydrogen Fuel Cell Bus Overview
    - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).
    - Describe HFCB operation and fuel cell function.
    - Define major subsystems unique to HFCBs:
        i. Hydrogen system
        ii. Air intake system

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| | iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>21. Apply safety practices when using meters.<br>22. Perform Live-Dead-Live testing on zero-emission vehicles.<br>23. Compare automotive multimeters' features and functions in practical applications.<br>24. Implement recommended practices for high-voltage measurement tools and techniques.<br>25. Diagnose and repair electrical faults effectively.<br>26. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>27. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 17. Identify electrical hazards and understand the potential injuries they can cause.<br>18. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>19. Recognize visual cues that indicate hazardous voltage presence.<br>20. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>21. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>22. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>23. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>24. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 21. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>22. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>23. Differentiate between various vehicle safety systems utilized in ZEBs.<br>24. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>25. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>26. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>27. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>28. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>29. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>30. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 19. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>20. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps). |

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| | - Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>21. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>22. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>23. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>24. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>25. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>26. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>27. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 31. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>32. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>33. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>34. Explain thermal runaway and its possible consequences in high voltage systems.<br>35. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>36. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>37. Outline emergency towing and extraction procedures, including securement points.<br>38. Identify components necessary for high voltage isolation.<br>39. Locate passenger emergency egress areas on BEBs and HFCBs.<br>40. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>41. Explain post-incident isolation procedures for high voltage systems.<br>42. Outline basic accident and incident protocols for key personnel.<br>43. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>44. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>45. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |

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| Contact Release | 15. Understand the purpose and significance of Contact Release in high-voltage environments.<br>16. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>17. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>18. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>19. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>20. Demonstrate the practical skills required to perform a Contact Release.<br>21. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 5. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>6. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 15. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>16. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>17. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>18. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>19. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>20. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>21. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |

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| Introduction to Troubleshooting | 35. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>36. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>37. Apply the four steps of troubleshooting to systematically resolve issues.<br>38. Conduct root cause analysis to identify underlying problems.<br>39. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>40. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>41. Master logic and elimination methods in diagnosing vehicle issues.<br>42. Explore and assess vehicle subsystems and their potential failures.<br>43. Diagnose component failures through systematic testing and analysis.<br>44. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>45. Conduct thorough component and electrical testing to confirm failures.<br>46. Measure performance to ensure effective diagnostics.<br>47. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>48. Identify and analyze software components and potential issues.<br>49. Analyze logs and fault data to inform troubleshooting processes.<br>50. Tackle complex and uncommon technical issues effectively.<br>51. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 11. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>12. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>13. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>14. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>15. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |

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| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 33. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>34. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>35. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>36. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>37. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>38. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>39. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>40. Thermal Management<br>- Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>41. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses. |

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| | - Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>42. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>43. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>44. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>45. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>46. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>47. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>48. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 19. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>20. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights. |

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| | 21. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>22. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>23. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>24. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.<br>- Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>25. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>26. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>27. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 23. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>24. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>25. Electrical Theory Application: |

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| | - Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>26. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>27. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>28. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>29. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>30. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>31. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>32. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>33. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |
| OSHA Basic Safety | 22. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>23. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>24. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>25. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>26. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>27. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>28. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 46. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>47. Energy Storage System (ESS) |

- Explain the purpose and major subcomponents of an ESS, including battery thermal management.
- Differentiate ESS design from low-voltage battery systems.
- Identify current ESS battery chemistries.
- Understand how capacitors function and compare to batteries.
- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.
- Explain the need for thermal management in ESS and associated equipment.
- Describe the functions of ESS conductors, junction boxes, and fuse boxes.

48. High Voltage Distribution
    - Explain the design and function of AC and DC high-voltage cables.
    - Describe shielding functions on high-voltage cables.
    - Understand the role of contactors and electrical switching devices in ZEBs.
    - Explain the purpose of bus bars and distribution blocks.
    - Describe insulation testing and its relationship with reference points.
    - Explain the correlation between AWG wire gauges and ratings.

49. Grounding and Bonding
    - Differentiate between grounding and bonding points and identify them.

50. High-Voltage Junction Box (HVJB)
    - Describe the purpose and benefits of an HVJB and its subcomponents.

51. Traction Motors
    - Explain the function of AC induction motors and regenerative braking.
    - Discuss the need for cooling systems in traction motors.

52. Power Electronics
    - Understand AC/DC characteristics and advantages of AC power in ZEBs.
    - Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.
    - Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.

53. Accessory Power (DC–DC)
    - Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

54. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

55. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

56. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.

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| | ii. Describe typical charging times.<br>iii. Explain advantages and disadvantages.<br>iv. Identify SAE standard J-2954/2.<br><br>57. Data Communication Networks<br>- Describe controller area network (CAN) protocols and standards.<br>- Identify CAN components:<br>i. Explain terminating resistors.<br>ii. Explain gateways.<br>iii. Explain shielding on data cables.<br>- Identify subsystems using CAN communication.<br>- Explain J1939 and data acquisition methods.<br>- Compare SAE, IEEE, and proprietary data.<br>- Explain communication between the charger and the bus.<br><br>58. Multiplexing (MUX)<br>- Describe multiplexing protocols and standards.<br>- Identify MUX network components.<br>- Identify subsystems using MUX communication.<br>- Explain J1213/1 and the "Glossary of Vehicle Networks for Multiplexing and Data Communications."<br><br>59. Telematics<br>- Describe vehicle telemetry system operation.<br>- Explain the function of gateways.<br>- Explain shielding on data cables.<br>- Explain communication with the vehicle's 12/24 V system through multiplexing.<br><br>60. Hydrogen Fuel Cell Bus Overview<br>- Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Describe HFCB operation and fuel cell function.<br>- Define major subsystems unique to HFCBs:<br>i. Hydrogen system<br>ii. Air intake system<br>iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>28. Apply safety practices when using meters.<br>29. Perform Live-Dead-Live testing on zero-emission vehicles.<br>30. Compare automotive multimeters' features and functions in practical applications.<br>31. Implement recommended practices for high-voltage measurement tools and techniques.<br>32. Diagnose and repair electrical faults effectively.<br>33. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>34. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |

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| HV Awareness Level 1 | 25. Identify electrical hazards and understand the potential injuries they can cause.<br>26. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>27. Recognize visual cues that indicate hazardous voltage presence.<br>28. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>29. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>30. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>31. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>32. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 31. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>32. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>33. Differentiate between various vehicle safety systems utilized in ZEBs.<br>34. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>35. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>36. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>37. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>38. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>39. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>40. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 28. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>29. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>30. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>31. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>32. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>33. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>34. Personal Protective Equipment (PPE): |

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| | - Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>35. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>36. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 46. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>47. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>48. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>49. Explain thermal runaway and its possible consequences in high voltage systems.<br>50. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>51. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>52. Outline emergency towing and extraction procedures, including securement points.<br>53. Identify components necessary for high voltage isolation.<br>54. Locate passenger emergency egress areas on BEBs and HFCBs.<br>55. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>56. Explain post-incident isolation procedures for high voltage systems.<br>57. Outline basic accident and incident protocols for key personnel.<br>58. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>59. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>60. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 22. Understand the purpose and significance of Contact Release in high-voltage environments.<br>23. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>24. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>25. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>26. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>27. Demonstrate the practical skills required to perform a Contact Release.<br>28. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 7. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>8. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |

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| ZEB/ZEV Electrical Theory | 22. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>23. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>24. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>25. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>26. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>27. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>28. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 52. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>53. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>54. Apply the four steps of troubleshooting to systematically resolve issues.<br>55. Conduct root cause analysis to identify underlying problems.<br>56. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>57. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>58. Master logic and elimination methods in diagnosing vehicle issues.<br>59. Explore and assess vehicle subsystems and their potential failures.<br>60. Diagnose component failures through systematic testing and analysis.<br>61. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>62. Conduct thorough component and electrical testing to confirm failures.<br>63. Measure performance to ensure effective diagnostics.<br>64. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>65. Identify and analyze software components and potential issues.<br>66. Analyze logs and fault data to inform troubleshooting processes.<br>67. Tackle complex and uncommon technical issues effectively.<br>68. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 16. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>17. Responder Information and Safety Protocols |

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| | - Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>18. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>19. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>20. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 49. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>50. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>51. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>52. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>53. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges. |

- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.

54. Power Supply and DC-DC Converters
    - Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).
    - Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.
    - List components that utilize LV power specific to Zero Emission Buses (ZEBs).
    - Explain the role of an LV battery equalizer.

55. Auxiliary Drive Motors
    - Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).
    - Utilize OEM schematics to pinpoint the electrical sources for these motors.

56. Thermal Management
    - Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).
    - Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).
    - Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.

57. HVAC Systems
    - Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.
    - Detail the HVAC components and explain the operation and purpose of the heat pump.

58. Auxiliary Heating Systems
    - Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.
    - Assess the advantages and disadvantages of each auxiliary heating system type.

59. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)
    - Explain the operation and components of main and auxiliary coolant loops in HFCBs.

60. Battery Electric Bus (BEB) Charging
    - Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.
    - Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.

61. Data Communication Networks
    - Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.
    - Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.

62. Multiplexing (MUX)
    - Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.

63. Telematics
    - Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.
    - Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.

64. Fuel Cell Basics

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| | - Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 28. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>29. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights.<br><br>30. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>31. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>32. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>33. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures. |

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| | - Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>34. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>35. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>36. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 34. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>35. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>36. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>37. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>38. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>39. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>40. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>41. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>42. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>43. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>44. Documentation and Communication: |

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| | - Accurately document diagnostic steps and communicate results clearly in maintenance reports. |
| OSHA Basic Safety | 29. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>30. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>31. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>32. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>33. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>34. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>35. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 61. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>62. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>63. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>64. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>65. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>66. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>67. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs. |

- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.
- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.

68. Accessory Power (DC–DC)
    - Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

69. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

70. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

71. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.
        ii. Describe typical charging times.
        iii. Explain advantages and disadvantages.
        iv. Identify SAE standard J-2954/2.

72. Data Communication Networks
    - Describe controller area network (CAN) protocols and standards.
    - Identify CAN components:
        i. Explain terminating resistors.
        ii. Explain gateways.
        iii. Explain shielding on data cables.
    - Identify subsystems using CAN communication.
    - Explain J1939 and data acquisition methods.
    - Compare SAE, IEEE, and proprietary data.
    - Explain communication between the charger and the bus.

73. Multiplexing (MUX)
    - Describe multiplexing protocols and standards.
    - Identify MUX network components.
    - Identify subsystems using MUX communication.
    - Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

74. Telematics
    - Describe vehicle telemetry system operation.
    - Explain the function of gateways.
    - Explain shielding on data cables.
    - Explain communication with the vehicle’s 12/24 V system through multiplexing.

75. Hydrogen Fuel Cell Bus Overview

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| | - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Describe HFCB operation and fuel cell function.<br>- Define major subsystems unique to HFCBs:<br>i. Hydrogen system<br>ii. Air intake system<br>iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>35. Apply safety practices when using meters.<br>36. Perform Live-Dead-Live testing on zero-emission vehicles.<br>37. Compare automotive multimeters' features and functions in practical applications.<br>38. Implement recommended practices for high-voltage measurement tools and techniques.<br>39. Diagnose and repair electrical faults effectively.<br>40. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>41. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 33. Identify electrical hazards and understand the potential injuries they can cause.<br>34. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>35. Recognize visual cues that indicate hazardous voltage presence.<br>36. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>37. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>38. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>39. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>40. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 41. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>42. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>43. Differentiate between various vehicle safety systems utilized in ZEBs.<br>44. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>45. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>46. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>47. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>48. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>49. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>50. Describe the ratings of PPE and their specific applications in high-voltage tasks. |

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| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 37. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>38. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>39. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>40. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>41. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>42. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>43. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>44. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>45. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 61. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>62. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>63. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>64. Explain thermal runaway and its possible consequences in high voltage systems.<br>65. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>66. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>67. Outline emergency towing and extraction procedures, including securement points.<br>68. Identify components necessary for high voltage isolation.<br>69. Locate passenger emergency egress areas on BEBs and HFCBs.<br>70. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>71. Explain post-incident isolation procedures for high voltage systems.<br>72. Outline basic accident and incident protocols for key personnel.<br>73. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses. |

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| | 74. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>75. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 29. Understand the purpose and significance of Contact Release in high-voltage environments.<br>30. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>31. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>32. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>33. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>34. Demonstrate the practical skills required to perform a Contact Release.<br>35. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 9. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>10. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 29. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>30. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>31. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>32. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>33. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>34. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement). |

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| | - Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>35. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 69. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>70. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>71. Apply the four steps of troubleshooting to systematically resolve issues.<br>72. Conduct root cause analysis to identify underlying problems.<br>73. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>74. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>75. Master logic and elimination methods in diagnosing vehicle issues.<br>76. Explore and assess vehicle subsystems and their potential failures.<br>77. Diagnose component failures through systematic testing and analysis.<br>78. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>79. Conduct thorough component and electrical testing to confirm failures.<br>80. Measure performance to ensure effective diagnostics.<br>81. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>82. Identify and analyze software components and potential issues.<br>83. Analyze logs and fault data to inform troubleshooting processes.<br>84. Tackle complex and uncommon technical issues effectively.<br>85. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 21. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>22. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>23. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>24. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>25. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity. |

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| | - Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 65. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>66. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>67. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>68. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>69. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>70. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>71. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>72. Thermal Management |

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| | - Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>73. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.<br>- Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>74. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>75. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>76. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>77. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>78. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>79. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>80. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 37. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>38. Maintenance Inspection Procedures: |

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| | | - Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights.<br><br>39. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>40. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>41. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>42. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.<br>- Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>43. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>44. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>45. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults. |

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| | - Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 45. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>46. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>47. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>48. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>49. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>50. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>51. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>52. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>53. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>54. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>55. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |

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| OSHA Basic Safety | 36. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>37. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>38. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>39. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>40. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>41. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>42. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 76. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>77. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>78. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>79. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>80. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>81. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>82. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs.<br>- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.<br>- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.<br><br>83. Accessory Power (DC–DC) |

- Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

84. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

85. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

86. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.
        ii. Describe typical charging times.
        iii. Explain advantages and disadvantages.
        iv. Identify SAE standard J-2954/2.

87. Data Communication Networks
    - Describe controller area network (CAN) protocols and standards.
    - Identify CAN components:
        i. Explain terminating resistors.
        ii. Explain gateways.
        iii. Explain shielding on data cables.
    - Identify subsystems using CAN communication.
    - Explain J1939 and data acquisition methods.
    - Compare SAE, IEEE, and proprietary data.
    - Explain communication between the charger and the bus.

88. Multiplexing (MUX)
    - Describe multiplexing protocols and standards.
    - Identify MUX network components.
    - Identify subsystems using MUX communication.
    - Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

89. Telematics
    - Describe vehicle telemetry system operation.
    - Explain the function of gateways.
    - Explain shielding on data cables.
    - Explain communication with the vehicle’s 12/24 V system through multiplexing.

90. Hydrogen Fuel Cell Bus Overview
    - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).
    - Describe HFCB operation and fuel cell function.
    - Define major subsystems unique to HFCBs:
        i. Hydrogen system
        ii. Air intake system

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| | iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>42. Apply safety practices when using meters.<br>43. Perform Live-Dead-Live testing on zero-emission vehicles.<br>44. Compare automotive multimeters' features and functions in practical applications.<br>45. Implement recommended practices for high-voltage measurement tools and techniques.<br>46. Diagnose and repair electrical faults effectively.<br>47. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>48. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 41. Identify electrical hazards and understand the potential injuries they can cause.<br>42. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>43. Recognize visual cues that indicate hazardous voltage presence.<br>44. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>45. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>46. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>47. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>48. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 51. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>52. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>53. Differentiate between various vehicle safety systems utilized in ZEBs.<br>54. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>55. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>56. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>57. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>58. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>59. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>60. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 46. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>47. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps). |

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| | - Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>48. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>49. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>50. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>51. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>52. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>53. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>54. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 76. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>77. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>78. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>79. Explain thermal runaway and its possible consequences in high voltage systems.<br>80. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>81. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>82. Outline emergency towing and extraction procedures, including securement points.<br>83. Identify components necessary for high voltage isolation.<br>84. Locate passenger emergency egress areas on BEBs and HFCBs.<br>85. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>86. Explain post-incident isolation procedures for high voltage systems.<br>87. Outline basic accident and incident protocols for key personnel.<br>88. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>89. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>90. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |

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| Contact Release | 36. Understand the purpose and significance of Contact Release in high-voltage environments.<br>37. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>38. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>39. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>40. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>41. Demonstrate the practical skills required to perform a Contact Release.<br>42. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 11. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>12. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 36. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>37. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>38. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>39. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>40. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>41. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>42. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |

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| Introduction to Troubleshooting | 86. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>87. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>88. Apply the four steps of troubleshooting to systematically resolve issues.<br>89. Conduct root cause analysis to identify underlying problems.<br>90. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>91. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>92. Master logic and elimination methods in diagnosing vehicle issues.<br>93. Explore and assess vehicle subsystems and their potential failures.<br>94. Diagnose component failures through systematic testing and analysis.<br>95. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>96. Conduct thorough component and electrical testing to confirm failures.<br>97. Measure performance to ensure effective diagnostics.<br>98. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>99. Identify and analyze software components and potential issues.<br>100. Analyze logs and fault data to inform troubleshooting processes.<br>101. Tackle complex and uncommon technical issues effectively.<br>102. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 26. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>27. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>28. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>29. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>30. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |

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| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 81. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>82. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>83. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>84. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>85. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>86. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>87. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>88. Thermal Management<br>- Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>89. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses. |

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| | - Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>90. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>91. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>92. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>93. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>94. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>95. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>96. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 46. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>47. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights. |

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| | 48. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>49. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>50. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>51. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.<br>- Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>52. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>53. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>54. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 56. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>57. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>58. Electrical Theory Application: |

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| | - Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>59. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>60. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>61. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>62. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>63. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>64. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>65. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>66. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |
| OSHA Basic Safety | 43. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>44. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>45. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>46. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>47. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>48. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>49. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 91. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>92. Energy Storage System (ESS) |

- Explain the purpose and major subcomponents of an ESS, including battery thermal management.
- Differentiate ESS design from low-voltage battery systems.
- Identify current ESS battery chemistries.
- Understand how capacitors function and compare to batteries.
- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.
- Explain the need for thermal management in ESS and associated equipment.
- Describe the functions of ESS conductors, junction boxes, and fuse boxes.

93. High Voltage Distribution
    - Explain the design and function of AC and DC high-voltage cables.
    - Describe shielding functions on high-voltage cables.
    - Understand the role of contactors and electrical switching devices in ZEBs.
    - Explain the purpose of bus bars and distribution blocks.
    - Describe insulation testing and its relationship with reference points.
    - Explain the correlation between AWG wire gauges and ratings.

94. Grounding and Bonding
    - Differentiate between grounding and bonding points and identify them.

95. High-Voltage Junction Box (HVJB)
    - Describe the purpose and benefits of an HVJB and its subcomponents.

96. Traction Motors
    - Explain the function of AC induction motors and regenerative braking.
    - Discuss the need for cooling systems in traction motors.

97. Power Electronics
    - Understand AC/DC characteristics and advantages of AC power in ZEBs.
    - Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.
    - Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.

98. Accessory Power (DC–DC)
    - Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

99. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

100. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

101. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.

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| | ii. Describe typical charging times.<br>iii. Explain advantages and disadvantages.<br>iv. Identify SAE standard J-2954/2.<br><br>102. Data Communication Networks<br>- Describe controller area network (CAN) protocols and standards.<br>- Identify CAN components:<br>i. Explain terminating resistors.<br>ii. Explain gateways.<br>iii. Explain shielding on data cables.<br>- Identify subsystems using CAN communication.<br>- Explain J1939 and data acquisition methods.<br>- Compare SAE, IEEE, and proprietary data.<br>- Explain communication between the charger and the bus.<br><br>103. Multiplexing (MUX)<br>- Describe multiplexing protocols and standards.<br>- Identify MUX network components.<br>- Identify subsystems using MUX communication.<br>- Explain J1213/1 and the "Glossary of Vehicle Networks for Multiplexing and Data Communications."<br><br>104. Telematics<br>- Describe vehicle telemetry system operation.<br>- Explain the function of gateways.<br>- Explain shielding on data cables.<br>- Explain communication with the vehicle's 12/24 V system through multiplexing.<br><br>105. Hydrogen Fuel Cell Bus Overview<br>- Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Describe HFCB operation and fuel cell function.<br>- Define major subsystems unique to HFCBs:<br>i. Hydrogen system<br>ii. Air intake system<br>iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>49. Apply safety practices when using meters.<br>50. Perform Live-Dead-Live testing on zero-emission vehicles.<br>51. Compare automotive multimeters' features and functions in practical applications.<br>52. Implement recommended practices for high-voltage measurement tools and techniques.<br>53. Diagnose and repair electrical faults effectively.<br>54. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>55. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |

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| HV Awareness Level 1 | 49. Identify electrical hazards and understand the potential injuries they can cause.<br>50. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>51. Recognize visual cues that indicate hazardous voltage presence.<br>52. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>53. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>54. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>55. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>56. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 61. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>62. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>63. Differentiate between various vehicle safety systems utilized in ZEBs.<br>64. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>65. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>66. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>67. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>68. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>69. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>70. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 55. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>56. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>57. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>58. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>59. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>60. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>61. Personal Protective Equipment (PPE): |

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| | - Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>62. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>63. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 91. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>92. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>93. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>94. Explain thermal runaway and its possible consequences in high voltage systems.<br>95. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>96. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>97. Outline emergency towing and extraction procedures, including securement points.<br>98. Identify components necessary for high voltage isolation.<br>99. Locate passenger emergency egress areas on BEBs and HFCBs.<br>100. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>101. Explain post-incident isolation procedures for high voltage systems.<br>102. Outline basic accident and incident protocols for key personnel.<br>103. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>104. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>105. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 43. Understand the purpose and significance of Contact Release in high-voltage environments.<br>44. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>45. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>46. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>47. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>48. Demonstrate the practical skills required to perform a Contact Release.<br>49. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 13. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>14. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |

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| ZEB/ZEV Electrical Theory | 43. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>44. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>45. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>46. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>47. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>48. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>49. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 103. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>104. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>105. Apply the four steps of troubleshooting to systematically resolve issues.<br>106. Conduct root cause analysis to identify underlying problems.<br>107. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>108. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>109. Master logic and elimination methods in diagnosing vehicle issues.<br>110. Explore and assess vehicle subsystems and their potential failures.<br>111. Diagnose component failures through systematic testing and analysis.<br>112. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>113. Conduct thorough component and electrical testing to confirm failures.<br>114. Measure performance to ensure effective diagnostics.<br>115. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>116. Identify and analyze software components and potential issues.<br>117. Analyze logs and fault data to inform troubleshooting processes.<br>118. Tackle complex and uncommon technical issues effectively.<br>119. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 31. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>32. Responder Information and Safety Protocols |

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| | - Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>33. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>34. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>35. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 97. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>98. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>99. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>100. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>101. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges. |

- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.

102. Power Supply and DC-DC Converters
    - Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).
    - Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.
    - List components that utilize LV power specific to Zero Emission Buses (ZEBs).
    - Explain the role of an LV battery equalizer.

103. Auxiliary Drive Motors
    - Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).
    - Utilize OEM schematics to pinpoint the electrical sources for these motors.

104. Thermal Management
    - Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).
    - Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).
    - Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.

105. HVAC Systems
    - Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.
    - Detail the HVAC components and explain the operation and purpose of the heat pump.

106. Auxiliary Heating Systems
    - Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.
    - Assess the advantages and disadvantages of each auxiliary heating system type.

107. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)
    - Explain the operation and components of main and auxiliary coolant loops in HFCBs.

108. Battery Electric Bus (BEB) Charging
    - Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.
    - Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.

109. Data Communication Networks
    - Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.
    - Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.

110. Multiplexing (MUX)
    - Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.

111. Telematics
    - Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.
    - Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.

112. Fuel Cell Basics

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| | - Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 55. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>56. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights.<br><br>57. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>58. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>59. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>60. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures. |

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| | - Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>61. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>62. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>63. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 67. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>68. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>69. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>70. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>71. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>72. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>73. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>74. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>75. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>76. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>77. Documentation and Communication: |

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| | - Accurately document diagnostic steps and communicate results clearly in maintenance reports. |
| OSHA Basic Safety | 50. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>51. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>52. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>53. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>54. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>55. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>56. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 106. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>107. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>108. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>109. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>110. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>111. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>112. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs. |

- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.
- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.

113. Accessory Power (DC–DC)
    - Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

114. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

115. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

116. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.
        ii. Describe typical charging times.
        iii. Explain advantages and disadvantages.
        iv. Identify SAE standard J-2954/2.

117. Data Communication Networks
    - Describe controller area network (CAN) protocols and standards.
    - Identify CAN components:
        i. Explain terminating resistors.
        ii. Explain gateways.
        iii. Explain shielding on data cables.
    - Identify subsystems using CAN communication.
    - Explain J1939 and data acquisition methods.
    - Compare SAE, IEEE, and proprietary data.
    - Explain communication between the charger and the bus.

118. Multiplexing (MUX)
    - Describe multiplexing protocols and standards.
    - Identify MUX network components.
    - Identify subsystems using MUX communication.
    - Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

119. Telematics
    - Describe vehicle telemetry system operation.
    - Explain the function of gateways.
    - Explain shielding on data cables.
    - Explain communication with the vehicle’s 12/24 V system through multiplexing.

120. Hydrogen Fuel Cell Bus Overview

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| | - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Describe HFCB operation and fuel cell function.<br>- Define major subsystems unique to HFCBs:<br>i. Hydrogen system<br>ii. Air intake system<br>iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>56. Apply safety practices when using meters.<br>57. Perform Live-Dead-Live testing on zero-emission vehicles.<br>58. Compare automotive multimeters' features and functions in practical applications.<br>59. Implement recommended practices for high-voltage measurement tools and techniques.<br>60. Diagnose and repair electrical faults effectively.<br>61. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>62. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 57. Identify electrical hazards and understand the potential injuries they can cause.<br>58. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>59. Recognize visual cues that indicate hazardous voltage presence.<br>60. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>61. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>62. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>63. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>64. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 71. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>72. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>73. Differentiate between various vehicle safety systems utilized in ZEBs.<br>74. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>75. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>76. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>77. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>78. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>79. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>80. Describe the ratings of PPE and their specific applications in high-voltage tasks. |

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| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 64. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>65. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>66. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>67. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>68. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>69. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>70. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>71. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>72. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 106. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>107. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>108. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>109. Explain thermal runaway and its possible consequences in high voltage systems.<br>110. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>111. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>112. Outline emergency towing and extraction procedures, including securement points.<br>113. Identify components necessary for high voltage isolation.<br>114. Locate passenger emergency egress areas on BEBs and HFCBs.<br>115. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>116. Explain post-incident isolation procedures for high voltage systems.<br>117. Outline basic accident and incident protocols for key personnel.<br>118. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses. |

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| | 119. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>120. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 50. Understand the purpose and significance of Contact Release in high-voltage environments.<br>51. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>52. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>53. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>54. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>55. Demonstrate the practical skills required to perform a Contact Release.<br>56. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 15. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>16. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 50. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>51. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>52. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>53. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>54. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>55. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement). |

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| | - Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>56. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 120. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>121. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>122. Apply the four steps of troubleshooting to systematically resolve issues.<br>123. Conduct root cause analysis to identify underlying problems.<br>124. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>125. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>126. Master logic and elimination methods in diagnosing vehicle issues.<br>127. Explore and assess vehicle subsystems and their potential failures.<br>128. Diagnose component failures through systematic testing and analysis.<br>129. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>130. Conduct thorough component and electrical testing to confirm failures.<br>131. Measure performance to ensure effective diagnostics.<br>132. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>133. Identify and analyze software components and potential issues.<br>134. Analyze logs and fault data to inform troubleshooting processes.<br>135. Tackle complex and uncommon technical issues effectively.<br>136. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 36. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>37. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>38. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>39. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>40. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity. |

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| | - Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 113. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>114. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>115. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>116. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>117. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>118. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>119. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>120. Thermal Management |

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| | - Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>121. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.<br>- Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>122. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>123. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>124. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>125. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>126. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>127. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>128. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 64. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>65. Maintenance Inspection Procedures: |

- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.
- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.
- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.
- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.
- Analyze historical telemetry data for performance insights.

66. Power Inverter/Power Electronics:
    - Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.
    - Troubleshoot power inverter faults in accordance with OEM standards.
    - Measure, interpret, and record power inverter resistance values.
    - Program inverters where applicable and diagnose the need for reprogramming or replacement.

67. Energy Storage Systems (ESS):
    - Follow OEM guidelines for the removal and replacement (R&R) of ESS components.
    - Safely troubleshoot ESS faults in accordance with OEM protocols.
    - Identify and repair ESS thermal management system faults.
    - Diagnose control system faults, including contactors and pre-charge resistors.
    - Perform battery balancing and string equalization using proper procedures.

68. Power Generation/Charging:
    - Adhere to OEM guidelines for R&R of power generation and charging components.
    - Troubleshoot power generation and charging faults according to OEM standards.
    - Inspect and repair all charging interfaces for damage or faults.
    - Differentiate between charger and bus-related faults and perform necessary repairs.
    - Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.
    - Test insulation resistance and determine deviations, repairing as needed.
    - Assess isolation resistance values, identify discrepancies, and implement repairs.

69. High-Voltage Cables:
    - Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.
    - Troubleshoot high-voltage cable and bus bar faults according to OEM standards.
    - Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.
    - Build or repair high-voltage cables, including stripping insulation and crimping lugs.

70. Traction Motors:
    - Understand and apply OEM guidelines for the repair and replacement of traction motor components.
    - Troubleshoot traction motor faults in accordance with OEM standards.
    - Conduct insulation and winding resistance tests on each motor phase.

71. Data Communication Networks:
    - Execute repair and replacement of data communication network components following OEM guidelines.
    - Troubleshoot faults within data communication networks based on OEM protocols.
    - Analyze and assess CAN network messages and integrity.
    - Utilize an oscilloscope to identify noise on the CAN bus network.
    - Analyze and graph live data, or interpret recent trace file data.
    - Perform root cause analysis of ZEB subsystems using fault data.

72. Control Systems:
    - Implement OEM guidelines for repairing and replacing control system components.
    - Diagnose control system faults in line with OEM troubleshooting procedures.
    - Interpret OEM schematics to identify control system faults.

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| | - Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 78. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>79. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>80. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>81. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>82. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>83. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>84. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>85. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>86. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>87. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>88. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |

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| OSHA Basic Safety | 57. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>58. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>59. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>60. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>61. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>62. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>63. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 121. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>122. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>123. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>124. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>125. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>126. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>127. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs.<br>- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.<br>- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.<br><br>128. Accessory Power (DC–DC) |

- Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

129. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

130. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

131. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.
        ii. Describe typical charging times.
        iii. Explain advantages and disadvantages.
        iv. Identify SAE standard J-2954/2.

132. Data Communication Networks
    - Describe controller area network (CAN) protocols and standards.
    - Identify CAN components:
        i. Explain terminating resistors.
        ii. Explain gateways.
        iii. Explain shielding on data cables.
    - Identify subsystems using CAN communication.
    - Explain J1939 and data acquisition methods.
    - Compare SAE, IEEE, and proprietary data.
    - Explain communication between the charger and the bus.

133. Multiplexing (MUX)
    - Describe multiplexing protocols and standards.
    - Identify MUX network components.
    - Identify subsystems using MUX communication.
    - Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

134. Telematics
    - Describe vehicle telemetry system operation.
    - Explain the function of gateways.
    - Explain shielding on data cables.
    - Explain communication with the vehicle’s 12/24 V system through multiplexing.

135. Hydrogen Fuel Cell Bus Overview
    - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).
    - Describe HFCB operation and fuel cell function.
    - Define major subsystems unique to HFCBs:
        i. Hydrogen system
        ii. Air intake system

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| | iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>63. Apply safety practices when using meters.<br>64. Perform Live-Dead-Live testing on zero-emission vehicles.<br>65. Compare automotive multimeters' features and functions in practical applications.<br>66. Implement recommended practices for high-voltage measurement tools and techniques.<br>67. Diagnose and repair electrical faults effectively.<br>68. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>69. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 65. Identify electrical hazards and understand the potential injuries they can cause.<br>66. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>67. Recognize visual cues that indicate hazardous voltage presence.<br>68. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>69. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>70. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>71. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>72. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 81. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>82. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>83. Differentiate between various vehicle safety systems utilized in ZEBs.<br>84. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>85. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>86. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>87. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>88. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>89. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>90. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 73. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>74. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps). |

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| | - Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>75. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>76. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>77. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>78. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>79. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>80. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>81. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 121. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>122. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>123. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>124. Explain thermal runaway and its possible consequences in high voltage systems.<br>125. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>126. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>127. Outline emergency towing and extraction procedures, including securement points.<br>128. Identify components necessary for high voltage isolation.<br>129. Locate passenger emergency egress areas on BEBs and HFCBs.<br>130. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>131. Explain post-incident isolation procedures for high voltage systems.<br>132. Outline basic accident and incident protocols for key personnel.<br>133. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>134. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>135. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |

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| Contact Release | 57. Understand the purpose and significance of Contact Release in high-voltage environments.<br>58. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>59. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>60. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>61. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>62. Demonstrate the practical skills required to perform a Contact Release.<br>63. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
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| ZEB/ZEV Electrical Theory | 57. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>58. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>59. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>60. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>61. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>62. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>63. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |

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| Introduction to Troubleshooting | 137. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>138. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>139. Apply the four steps of troubleshooting to systematically resolve issues.<br>140. Conduct root cause analysis to identify underlying problems.<br>141. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>142. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>143. Master logic and elimination methods in diagnosing vehicle issues.<br>144. Explore and assess vehicle subsystems and their potential failures.<br>145. Diagnose component failures through systematic testing and analysis.<br>146. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>147. Conduct thorough component and electrical testing to confirm failures.<br>148. Measure performance to ensure effective diagnostics.<br>149. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>150. Identify and analyze software components and potential issues.<br>151. Analyze logs and fault data to inform troubleshooting processes.<br>152. Tackle complex and uncommon technical issues effectively.<br>153. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 41. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>42. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>43. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>44. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>45. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |

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| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 129. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>130. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>131. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>132. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>133. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>134. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>135. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>136. Thermal Management<br>- Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>137. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses. |

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| | - Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>138. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>139. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>140. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>141. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>142. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>143. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>144. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 73. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>74. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights. |

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| | 75. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>76. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>77. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>78. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.<br>- Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>79. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>80. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>81. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 89. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>90. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>91. Electrical Theory Application: |

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| | - Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>92. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>93. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>94. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>95. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>96. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>97. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>98. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>99. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |
| OSHA Basic Safety | 64. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>65. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>66. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>67. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>68. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>69. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>70. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 136. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>137. Energy Storage System (ESS) |

- Explain the purpose and major subcomponents of an ESS, including battery thermal management.
- Differentiate ESS design from low-voltage battery systems.
- Identify current ESS battery chemistries.
- Understand how capacitors function and compare to batteries.
- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.
- Explain the need for thermal management in ESS and associated equipment.
- Describe the functions of ESS conductors, junction boxes, and fuse boxes.

138. High Voltage Distribution
    - Explain the design and function of AC and DC high-voltage cables.
    - Describe shielding functions on high-voltage cables.
    - Understand the role of contactors and electrical switching devices in ZEBs.
    - Explain the purpose of bus bars and distribution blocks.
    - Describe insulation testing and its relationship with reference points.
    - Explain the correlation between AWG wire gauges and ratings.

139. Grounding and Bonding
    - Differentiate between grounding and bonding points and identify them.

140. High-Voltage Junction Box (HVJB)
    - Describe the purpose and benefits of an HVJB and its subcomponents.

141. Traction Motors
    - Explain the function of AC induction motors and regenerative braking.
    - Discuss the need for cooling systems in traction motors.

142. Power Electronics
    - Understand AC/DC characteristics and advantages of AC power in ZEBs.
    - Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.
    - Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.

143. Accessory Power (DC–DC)
    - Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

144. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

145. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

146. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.

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| | ii. Describe typical charging times.<br>iii. Explain advantages and disadvantages.<br>iv. Identify SAE standard J-2954/2.<br><br>147. Data Communication Networks<br>- Describe controller area network (CAN) protocols and standards.<br>- Identify CAN components:<br>i. Explain terminating resistors.<br>ii. Explain gateways.<br>iii. Explain shielding on data cables.<br>- Identify subsystems using CAN communication.<br>- Explain J1939 and data acquisition methods.<br>- Compare SAE, IEEE, and proprietary data.<br>- Explain communication between the charger and the bus.<br><br>148. Multiplexing (MUX)<br>- Describe multiplexing protocols and standards.<br>- Identify MUX network components.<br>- Identify subsystems using MUX communication.<br>- Explain J1213/1 and the "Glossary of Vehicle Networks for Multiplexing and Data Communications."<br><br>149. Telematics<br>- Describe vehicle telemetry system operation.<br>- Explain the function of gateways.<br>- Explain shielding on data cables.<br>- Explain communication with the vehicle's 12/24 V system through multiplexing.<br><br>150. Hydrogen Fuel Cell Bus Overview<br>- Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Describe HFCB operation and fuel cell function.<br>- Define major subsystems unique to HFCBs:<br>i. Hydrogen system<br>ii. Air intake system<br>iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>70. Apply safety practices when using meters.<br>71. Perform Live-Dead-Live testing on zero-emission vehicles.<br>72. Compare automotive multimeters' features and functions in practical applications.<br>73. Implement recommended practices for high-voltage measurement tools and techniques.<br>74. Diagnose and repair electrical faults effectively.<br>75. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>76. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |

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| HV Awareness Level 1 | 73. Identify electrical hazards and understand the potential injuries they can cause.<br>74. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>75. Recognize visual cues that indicate hazardous voltage presence.<br>76. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>77. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>78. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>79. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>80. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 91. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>92. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>93. Differentiate between various vehicle safety systems utilized in ZEBs.<br>94. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>95. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>96. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>97. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>98. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>99. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>100. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 82. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>83. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>84. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>85. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>86. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>87. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>88. Personal Protective Equipment (PPE): |

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| | - Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>89. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>90. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 136. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>137. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>138. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>139. Explain thermal runaway and its possible consequences in high voltage systems.<br>140. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>141. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>142. Outline emergency towing and extraction procedures, including securement points.<br>143. Identify components necessary for high voltage isolation.<br>144. Locate passenger emergency egress areas on BEBs and HFCBs.<br>145. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>146. Explain post-incident isolation procedures for high voltage systems.<br>147. Outline basic accident and incident protocols for key personnel.<br>148. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>149. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>150. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 64. Understand the purpose and significance of Contact Release in high-voltage environments.<br>65. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>66. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>67. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>68. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>69. Demonstrate the practical skills required to perform a Contact Release.<br>70. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 19. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>20. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |

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| ZEB/ZEV Electrical Theory | 64. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>65. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>66. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>67. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>68. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>69. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>70. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 154. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>155. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>156. Apply the four steps of troubleshooting to systematically resolve issues.<br>157. Conduct root cause analysis to identify underlying problems.<br>158. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>159. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>160. Master logic and elimination methods in diagnosing vehicle issues.<br>161. Explore and assess vehicle subsystems and their potential failures.<br>162. Diagnose component failures through systematic testing and analysis.<br>163. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>164. Conduct thorough component and electrical testing to confirm failures.<br>165. Measure performance to ensure effective diagnostics.<br>166. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>167. Identify and analyze software components and potential issues.<br>168. Analyze logs and fault data to inform troubleshooting processes.<br>169. Tackle complex and uncommon technical issues effectively.<br>170. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 46. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>47. Responder Information and Safety Protocols |

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| | - Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>48. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>49. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>50. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 145. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>146. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>147. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>148. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>149. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges. |

- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.

150. Power Supply and DC-DC Converters
    - Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).
    - Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.
    - List components that utilize LV power specific to Zero Emission Buses (ZEBs).
    - Explain the role of an LV battery equalizer.

151. Auxiliary Drive Motors
    - Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).
    - Utilize OEM schematics to pinpoint the electrical sources for these motors.

152. Thermal Management
    - Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).
    - Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).
    - Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.

153. HVAC Systems
    - Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.
    - Detail the HVAC components and explain the operation and purpose of the heat pump.

154. Auxiliary Heating Systems
    - Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.
    - Assess the advantages and disadvantages of each auxiliary heating system type.

155. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)
    - Explain the operation and components of main and auxiliary coolant loops in HFCBs.

156. Battery Electric Bus (BEB) Charging
    - Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.
    - Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.

157. Data Communication Networks
    - Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.
    - Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.

158. Multiplexing (MUX)
    - Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.

159. Telematics
    - Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.
    - Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.

160. Fuel Cell Basics

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| | - Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 82. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>83. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights.<br><br>84. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>85. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>86. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>87. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures. |

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| | - Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>88. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>89. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>90. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 100. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>101. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>102. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>103. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>104. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>105. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>106. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>107. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>108. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>109. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>110. Documentation and Communication: |

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| | - Accurately document diagnostic steps and communicate results clearly in maintenance reports. |
| OSHA Basic Safety | 71. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>72. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>73. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>74. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>75. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>76. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>77. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 151. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>152. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>153. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>154. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>155. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>156. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>157. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs. |

- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.
- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.

158. Accessory Power (DC–DC)
- Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

159. Accessory Motors
- Explain the need for motor-driven accessories and identify examples in ZEBs.
- Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

160. Thermal Management Systems
- Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
- Describe the function of coolant loops and their integration with HVAC systems.
- Discuss auxiliary heaters in relation to propulsion and battery thermal management.

161. Charging Systems
- Plug-in (Conductive)
    i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
    ii. Identify relevant SAE standards and typical charging times.
    iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

- Overhead (Conductive)
    i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
    ii. Explain advantages and disadvantages related to overhead charging systems.

- Inductive Charging
    i. Define inductive charging.
    ii. Describe typical charging times.
    iii. Explain advantages and disadvantages.
    iv. Identify SAE standard J-2954/2.

162. Data Communication Networks
- Describe controller area network (CAN) protocols and standards.
- Identify CAN components:
    i. Explain terminating resistors.
    ii. Explain gateways.
    iii. Explain shielding on data cables.
- Identify subsystems using CAN communication.
- Explain J1939 and data acquisition methods.
- Compare SAE, IEEE, and proprietary data.
- Explain communication between the charger and the bus.

163. Multiplexing (MUX)
- Describe multiplexing protocols and standards.
- Identify MUX network components.
- Identify subsystems using MUX communication.
- Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

164. Telematics
- Describe vehicle telemetry system operation.
- Explain the function of gateways.
- Explain shielding on data cables.
- Explain communication with the vehicle’s 12/24 V system through multiplexing.

165. Hydrogen Fuel Cell Bus Overview

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| | - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Describe HFCB operation and fuel cell function.<br>- Define major subsystems unique to HFCBs:<br>i. Hydrogen system<br>ii. Air intake system<br>iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>77. Apply safety practices when using meters.<br>78. Perform Live-Dead-Live testing on zero-emission vehicles.<br>79. Compare automotive multimeters' features and functions in practical applications.<br>80. Implement recommended practices for high-voltage measurement tools and techniques.<br>81. Diagnose and repair electrical faults effectively.<br>82. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>83. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 81. Identify electrical hazards and understand the potential injuries they can cause.<br>82. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>83. Recognize visual cues that indicate hazardous voltage presence.<br>84. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>85. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>86. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>87. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>88. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 101. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>102. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>103. Differentiate between various vehicle safety systems utilized in ZEBs.<br>104. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>105. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>106. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>107. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>108. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>109. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>110. Describe the ratings of PPE and their specific applications in high-voltage tasks. |

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| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 91. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>92. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>93. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>94. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>95. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>96. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>97. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>98. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>99. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 151. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>152. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>153. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>154. Explain thermal runaway and its possible consequences in high voltage systems.<br>155. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>156. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>157. Outline emergency towing and extraction procedures, including securement points.<br>158. Identify components necessary for high voltage isolation.<br>159. Locate passenger emergency egress areas on BEBs and HFCBs.<br>160. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>161. Explain post-incident isolation procedures for high voltage systems.<br>162. Outline basic accident and incident protocols for key personnel.<br>163. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses. |

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| | 164. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>165. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 71. Understand the purpose and significance of Contact Release in high-voltage environments.<br>72. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>73. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>74. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>75. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>76. Demonstrate the practical skills required to perform a Contact Release.<br>77. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 21. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>22. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 71. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>72. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>73. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>74. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>75. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>76. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement). |

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| | - Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>77. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 171. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>172. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>173. Apply the four steps of troubleshooting to systematically resolve issues.<br>174. Conduct root cause analysis to identify underlying problems.<br>175. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>176. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>177. Master logic and elimination methods in diagnosing vehicle issues.<br>178. Explore and assess vehicle subsystems and their potential failures.<br>179. Diagnose component failures through systematic testing and analysis.<br>180. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>181. Conduct thorough component and electrical testing to confirm failures.<br>182. Measure performance to ensure effective diagnostics.<br>183. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>184. Identify and analyze software components and potential issues.<br>185. Analyze logs and fault data to inform troubleshooting processes.<br>186. Tackle complex and uncommon technical issues effectively.<br>187. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 51. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>52. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>53. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>54. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>55. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity. |

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| | - Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 161. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>162. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>163. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>164. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>165. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>166. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>167. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>168. Thermal Management |

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| | - Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>169. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.<br>- Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>170. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>171. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>172. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>173. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>174. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>175. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>176. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 91. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>92. Maintenance Inspection Procedures: |

- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.
- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.
- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.
- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.
- Analyze historical telemetry data for performance insights.

93. Power Inverter/Power Electronics:
    - Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.
    - Troubleshoot power inverter faults in accordance with OEM standards.
    - Measure, interpret, and record power inverter resistance values.
    - Program inverters where applicable and diagnose the need for reprogramming or replacement.

94. Energy Storage Systems (ESS):
    - Follow OEM guidelines for the removal and replacement (R&R) of ESS components.
    - Safely troubleshoot ESS faults in accordance with OEM protocols.
    - Identify and repair ESS thermal management system faults.
    - Diagnose control system faults, including contactors and pre-charge resistors.
    - Perform battery balancing and string equalization using proper procedures.

95. Power Generation/Charging:
    - Adhere to OEM guidelines for R&R of power generation and charging components.
    - Troubleshoot power generation and charging faults according to OEM standards.
    - Inspect and repair all charging interfaces for damage or faults.
    - Differentiate between charger and bus-related faults and perform necessary repairs.
    - Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.
    - Test insulation resistance and determine deviations, repairing as needed.
    - Assess isolation resistance values, identify discrepancies, and implement repairs.

96. High-Voltage Cables:
    - Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.
    - Troubleshoot high-voltage cable and bus bar faults according to OEM standards.
    - Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.
    - Build or repair high-voltage cables, including stripping insulation and crimping lugs.

97. Traction Motors:
    - Understand and apply OEM guidelines for the repair and replacement of traction motor components.
    - Troubleshoot traction motor faults in accordance with OEM standards.
    - Conduct insulation and winding resistance tests on each motor phase.

98. Data Communication Networks:
    - Execute repair and replacement of data communication network components following OEM guidelines.
    - Troubleshoot faults within data communication networks based on OEM protocols.
    - Analyze and assess CAN network messages and integrity.
    - Utilize an oscilloscope to identify noise on the CAN bus network.
    - Analyze and graph live data, or interpret recent trace file data.
    - Perform root cause analysis of ZEB subsystems using fault data.

99. Control Systems:
    - Implement OEM guidelines for repairing and replacing control system components.
    - Diagnose control system faults in line with OEM troubleshooting procedures.
    - Interpret OEM schematics to identify control system faults.

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| | - Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 111. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>112. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>113. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>114. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>115. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>116. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>117. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>118. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>119. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>120. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>121. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |

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| OSHA Basic Safety | 78. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>79. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>80. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>81. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>82. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>83. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>84. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 166. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>167. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>168. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>169. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>170. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>171. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>172. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs.<br>- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.<br>- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.<br><br>173. Accessory Power (DC–DC) |

- Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

174. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

175. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

176. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.
        ii. Describe typical charging times.
        iii. Explain advantages and disadvantages.
        iv. Identify SAE standard J-2954/2.

177. Data Communication Networks
    - Describe controller area network (CAN) protocols and standards.
    - Identify CAN components:
        i. Explain terminating resistors.
        ii. Explain gateways.
        iii. Explain shielding on data cables.
    - Identify subsystems using CAN communication.
    - Explain J1939 and data acquisition methods.
    - Compare SAE, IEEE, and proprietary data.
    - Explain communication between the charger and the bus.

178. Multiplexing (MUX)
    - Describe multiplexing protocols and standards.
    - Identify MUX network components.
    - Identify subsystems using MUX communication.
    - Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

179. Telematics
    - Describe vehicle telemetry system operation.
    - Explain the function of gateways.
    - Explain shielding on data cables.
    - Explain communication with the vehicle’s 12/24 V system through multiplexing.

180. Hydrogen Fuel Cell Bus Overview
    - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).
    - Describe HFCB operation and fuel cell function.
    - Define major subsystems unique to HFCBs:
        i. Hydrogen system
        ii. Air intake system

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| | iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>84. Apply safety practices when using meters.<br>85. Perform Live-Dead-Live testing on zero-emission vehicles.<br>86. Compare automotive multimeters' features and functions in practical applications.<br>87. Implement recommended practices for high-voltage measurement tools and techniques.<br>88. Diagnose and repair electrical faults effectively.<br>89. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>90. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 89. Identify electrical hazards and understand the potential injuries they can cause.<br>90. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>91. Recognize visual cues that indicate hazardous voltage presence.<br>92. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>93. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>94. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>95. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>96. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 111. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>112. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>113. Differentiate between various vehicle safety systems utilized in ZEBs.<br>114. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>115. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>116. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>117. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>118. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>119. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>120. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 100. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>101. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps). |

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| | - Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>102. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>103. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>104. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>105. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>106. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>107. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>108. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 166. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>167. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>168. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>169. Explain thermal runaway and its possible consequences in high voltage systems.<br>170. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>171. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>172. Outline emergency towing and extraction procedures, including securement points.<br>173. Identify components necessary for high voltage isolation.<br>174. Locate passenger emergency egress areas on BEBs and HFCBs.<br>175. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>176. Explain post-incident isolation procedures for high voltage systems.<br>177. Outline basic accident and incident protocols for key personnel.<br>178. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>179. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>180. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |

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| Contact Release | 78. Understand the purpose and significance of Contact Release in high-voltage environments.<br>79. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>80. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>81. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>82. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>83. Demonstrate the practical skills required to perform a Contact Release.<br>84. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 23. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>24. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 78. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>79. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>80. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>81. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>82. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>83. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>84. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |

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| Introduction to Troubleshooting | 188. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>189. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>190. Apply the four steps of troubleshooting to systematically resolve issues.<br>191. Conduct root cause analysis to identify underlying problems.<br>192. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>193. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>194. Master logic and elimination methods in diagnosing vehicle issues.<br>195. Explore and assess vehicle subsystems and their potential failures.<br>196. Diagnose component failures through systematic testing and analysis.<br>197. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>198. Conduct thorough component and electrical testing to confirm failures.<br>199. Measure performance to ensure effective diagnostics.<br>200. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>201. Identify and analyze software components and potential issues.<br>202. Analyze logs and fault data to inform troubleshooting processes.<br>203. Tackle complex and uncommon technical issues effectively.<br>204. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 56. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>57. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>58. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>59. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>60. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |

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| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 177. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>178. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>179. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>180. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>181. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>182. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>183. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>184. Thermal Management<br>- Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>185. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses. |

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| | - Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>186. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>187. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>188. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>189. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>190. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>191. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>192. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 100. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>101. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights. |

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| | 102. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>103. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>104. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>105. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.<br>- Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>106. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>107. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>108. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 122. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>123. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>124. Electrical Theory Application: |

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| | - Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>125. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>126. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>127. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>128. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>129. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>130. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>131. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>132. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |
| OSHA Basic Safety | 85. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>86. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>87. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>88. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>89. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>90. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>91. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 181. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>182. Energy Storage System (ESS) |

- Explain the purpose and major subcomponents of an ESS, including battery thermal management.
- Differentiate ESS design from low-voltage battery systems.
- Identify current ESS battery chemistries.
- Understand how capacitors function and compare to batteries.
- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.
- Explain the need for thermal management in ESS and associated equipment.
- Describe the functions of ESS conductors, junction boxes, and fuse boxes.

183. High Voltage Distribution
    - Explain the design and function of AC and DC high-voltage cables.
    - Describe shielding functions on high-voltage cables.
    - Understand the role of contactors and electrical switching devices in ZEBs.
    - Explain the purpose of bus bars and distribution blocks.
    - Describe insulation testing and its relationship with reference points.
    - Explain the correlation between AWG wire gauges and ratings.

184. Grounding and Bonding
    - Differentiate between grounding and bonding points and identify them.

185. High-Voltage Junction Box (HVJB)
    - Describe the purpose and benefits of an HVJB and its subcomponents.

186. Traction Motors
    - Explain the function of AC induction motors and regenerative braking.
    - Discuss the need for cooling systems in traction motors.

187. Power Electronics
    - Understand AC/DC characteristics and advantages of AC power in ZEBs.
    - Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.
    - Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.

188. Accessory Power (DC–DC)
    - Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

189. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

190. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

191. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.

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| | ii. Describe typical charging times.<br>iii. Explain advantages and disadvantages.<br>iv. Identify SAE standard J-2954/2.<br><br>192. Data Communication Networks<br>- Describe controller area network (CAN) protocols and standards.<br>- Identify CAN components:<br>i. Explain terminating resistors.<br>ii. Explain gateways.<br>iii. Explain shielding on data cables.<br>- Identify subsystems using CAN communication.<br>- Explain J1939 and data acquisition methods.<br>- Compare SAE, IEEE, and proprietary data.<br>- Explain communication between the charger and the bus.<br><br>193. Multiplexing (MUX)<br>- Describe multiplexing protocols and standards.<br>- Identify MUX network components.<br>- Identify subsystems using MUX communication.<br>- Explain J1213/1 and the "Glossary of Vehicle Networks for Multiplexing and Data Communications."<br><br>194. Telematics<br>- Describe vehicle telemetry system operation.<br>- Explain the function of gateways.<br>- Explain shielding on data cables.<br>- Explain communication with the vehicle's 12/24 V system through multiplexing.<br><br>195. Hydrogen Fuel Cell Bus Overview<br>- Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Describe HFCB operation and fuel cell function.<br>- Define major subsystems unique to HFCBs:<br>i. Hydrogen system<br>ii. Air intake system<br>iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>91. Apply safety practices when using meters.<br>92. Perform Live-Dead-Live testing on zero-emission vehicles.<br>93. Compare automotive multimeters' features and functions in practical applications.<br>94. Implement recommended practices for high-voltage measurement tools and techniques.<br>95. Diagnose and repair electrical faults effectively.<br>96. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>97. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |

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| HV Awareness Level 1 | 97. Identify electrical hazards and understand the potential injuries they can cause.<br>98. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>99. Recognize visual cues that indicate hazardous voltage presence.<br>100. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>101. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>102. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>103. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>104. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 121. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>122. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>123. Differentiate between various vehicle safety systems utilized in ZEBs.<br>124. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>125. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>126. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>127. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>128. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>129. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>130. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 109. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>110. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>111. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>112. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>113. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>114. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>115. Personal Protective Equipment (PPE): |

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| | - Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>116. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>117. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 181. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>182. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>183. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>184. Explain thermal runaway and its possible consequences in high voltage systems.<br>185. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>186. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>187. Outline emergency towing and extraction procedures, including securement points.<br>188. Identify components necessary for high voltage isolation.<br>189. Locate passenger emergency egress areas on BEBs and HFCBs.<br>190. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>191. Explain post-incident isolation procedures for high voltage systems.<br>192. Outline basic accident and incident protocols for key personnel.<br>193. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>194. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>195. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 85. Understand the purpose and significance of Contact Release in high-voltage environments.<br>86. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>87. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>88. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>89. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>90. Demonstrate the practical skills required to perform a Contact Release.<br>91. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 25. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>26. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |

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| ZEB/ZEV Electrical Theory | 85. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>86. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>87. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>88. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>89. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>90. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>91. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 205. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>206. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>207. Apply the four steps of troubleshooting to systematically resolve issues.<br>208. Conduct root cause analysis to identify underlying problems.<br>209. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>210. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>211. Master logic and elimination methods in diagnosing vehicle issues.<br>212. Explore and assess vehicle subsystems and their potential failures.<br>213. Diagnose component failures through systematic testing and analysis.<br>214. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>215. Conduct thorough component and electrical testing to confirm failures.<br>216. Measure performance to ensure effective diagnostics.<br>217. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>218. Identify and analyze software components and potential issues.<br>219. Analyze logs and fault data to inform troubleshooting processes.<br>220. Tackle complex and uncommon technical issues effectively.<br>221. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 61. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>62. Responder Information and Safety Protocols |

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| | - Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>63. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>64. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>65. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 193. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>194. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>195. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>196. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>197. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges. |

- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.

198. Power Supply and DC-DC Converters
    - Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).
    - Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.
    - List components that utilize LV power specific to Zero Emission Buses (ZEBs).
    - Explain the role of an LV battery equalizer.

199. Auxiliary Drive Motors
    - Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).
    - Utilize OEM schematics to pinpoint the electrical sources for these motors.

200. Thermal Management
    - Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).
    - Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).
    - Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.

201. HVAC Systems
    - Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.
    - Detail the HVAC components and explain the operation and purpose of the heat pump.

202. Auxiliary Heating Systems
    - Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.
    - Assess the advantages and disadvantages of each auxiliary heating system type.

203. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)
    - Explain the operation and components of main and auxiliary coolant loops in HFCBs.

204. Battery Electric Bus (BEB) Charging
    - Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.
    - Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.

205. Data Communication Networks
    - Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.
    - Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.

206. Multiplexing (MUX)
    - Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.

207. Telematics
    - Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.
    - Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.

208. Fuel Cell Basics

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| | - Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 109. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>110. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights.<br><br>111. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>112. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>113. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>114. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures. |

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| | - Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>115. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>116. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>117. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 133. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>134. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>135. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>136. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>137. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>138. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>139. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>140. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>141. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>142. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>143. Documentation and Communication: |

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| | - Accurately document diagnostic steps and communicate results clearly in maintenance reports. |
| OSHA Basic Safety | 92. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>93. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>94. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>95. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>96. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>97. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>98. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 196. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>197. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>198. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>199. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>200. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>201. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>202. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs. |

- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.
- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.

203. Accessory Power (DC–DC)
- Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

204. Accessory Motors
- Explain the need for motor-driven accessories and identify examples in ZEBs.
- Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

205. Thermal Management Systems
- Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
- Describe the function of coolant loops and their integration with HVAC systems.
- Discuss auxiliary heaters in relation to propulsion and battery thermal management.

206. Charging Systems
- Plug-in (Conductive)
    i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
    ii. Identify relevant SAE standards and typical charging times.
    iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

- Overhead (Conductive)
    i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
    ii. Explain advantages and disadvantages related to overhead charging systems.

- Inductive Charging
    i. Define inductive charging.
    ii. Describe typical charging times.
    iii. Explain advantages and disadvantages.
    iv. Identify SAE standard J-2954/2.

207. Data Communication Networks
- Describe controller area network (CAN) protocols and standards.
- Identify CAN components:
    i. Explain terminating resistors.
    ii. Explain gateways.
    iii. Explain shielding on data cables.
- Identify subsystems using CAN communication.
- Explain J1939 and data acquisition methods.
- Compare SAE, IEEE, and proprietary data.
- Explain communication between the charger and the bus.

208. Multiplexing (MUX)
- Describe multiplexing protocols and standards.
- Identify MUX network components.
- Identify subsystems using MUX communication.
- Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

209. Telematics
- Describe vehicle telemetry system operation.
- Explain the function of gateways.
- Explain shielding on data cables.
- Explain communication with the vehicle’s 12/24 V system through multiplexing.

210. Hydrogen Fuel Cell Bus Overview

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| | - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Describe HFCB operation and fuel cell function.<br>- Define major subsystems unique to HFCBs:<br>i. Hydrogen system<br>ii. Air intake system<br>iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>98. Apply safety practices when using meters.<br>99. Perform Live-Dead-Live testing on zero-emission vehicles.<br>100. Compare automotive multimeters' features and functions in practical applications.<br>101. Implement recommended practices for high-voltage measurement tools and techniques.<br>102. Diagnose and repair electrical faults effectively.<br>103. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>104. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 105. Identify electrical hazards and understand the potential injuries they can cause.<br>106. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>107. Recognize visual cues that indicate hazardous voltage presence.<br>108. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>109. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>110. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>111. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>112. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 131. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>132. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>133. Differentiate between various vehicle safety systems utilized in ZEBs.<br>134. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>135. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>136. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>137. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>138. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>139. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>140. Describe the ratings of PPE and their specific applications in high-voltage tasks. |

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| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 118. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>119. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps).<br>- Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>120. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>121. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>122. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>123. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>124. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>125. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>126. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 196. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>197. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>198. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>199. Explain thermal runaway and its possible consequences in high voltage systems.<br>200. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>201. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>202. Outline emergency towing and extraction procedures, including securement points.<br>203. Identify components necessary for high voltage isolation.<br>204. Locate passenger emergency egress areas on BEBs and HFCBs.<br>205. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>206. Explain post-incident isolation procedures for high voltage systems.<br>207. Outline basic accident and incident protocols for key personnel.<br>208. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses. |

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| | 209. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>210. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |
| Contact Release | 92. Understand the purpose and significance of Contact Release in high-voltage environments.<br>93. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>94. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>95. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>96. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>97. Demonstrate the practical skills required to perform a Contact Release.<br>98. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 27. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>28. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 92. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>93. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>94. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>95. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>96. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>97. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement). |

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| | - Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>98. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |
| Introduction to Troubleshooting | 222. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>223. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>224. Apply the four steps of troubleshooting to systematically resolve issues.<br>225. Conduct root cause analysis to identify underlying problems.<br>226. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>227. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>228. Master logic and elimination methods in diagnosing vehicle issues.<br>229. Explore and assess vehicle subsystems and their potential failures.<br>230. Diagnose component failures through systematic testing and analysis.<br>231. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>232. Conduct thorough component and electrical testing to confirm failures.<br>233. Measure performance to ensure effective diagnostics.<br>234. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>235. Identify and analyze software components and potential issues.<br>236. Analyze logs and fault data to inform troubleshooting processes.<br>237. Tackle complex and uncommon technical issues effectively.<br>238. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 66. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>67. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>68. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>69. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>70. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity. |

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| | - Demonstrate proper usage of insulated tools during work tasks. |
| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 209. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>210. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>211. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>212. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>213. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>214. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>215. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>216. Thermal Management |

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| | - Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>217. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses.<br>- Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>218. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>219. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>220. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>221. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>222. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>223. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>224. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 118. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>119. Maintenance Inspection Procedures: |

- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.
- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.
- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.
- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.
- Analyze historical telemetry data for performance insights.

120. Power Inverter/Power Electronics:
    - Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.
    - Troubleshoot power inverter faults in accordance with OEM standards.
    - Measure, interpret, and record power inverter resistance values.
    - Program inverters where applicable and diagnose the need for reprogramming or replacement.

121. Energy Storage Systems (ESS):
    - Follow OEM guidelines for the removal and replacement (R&R) of ESS components.
    - Safely troubleshoot ESS faults in accordance with OEM protocols.
    - Identify and repair ESS thermal management system faults.
    - Diagnose control system faults, including contactors and pre-charge resistors.
    - Perform battery balancing and string equalization using proper procedures.

122. Power Generation/Charging:
    - Adhere to OEM guidelines for R&R of power generation and charging components.
    - Troubleshoot power generation and charging faults according to OEM standards.
    - Inspect and repair all charging interfaces for damage or faults.
    - Differentiate between charger and bus-related faults and perform necessary repairs.
    - Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.
    - Test insulation resistance and determine deviations, repairing as needed.
    - Assess isolation resistance values, identify discrepancies, and implement repairs.

123. High-Voltage Cables:
    - Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.
    - Troubleshoot high-voltage cable and bus bar faults according to OEM standards.
    - Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.
    - Build or repair high-voltage cables, including stripping insulation and crimping lugs.

124. Traction Motors:
    - Understand and apply OEM guidelines for the repair and replacement of traction motor components.
    - Troubleshoot traction motor faults in accordance with OEM standards.
    - Conduct insulation and winding resistance tests on each motor phase.

125. Data Communication Networks:
    - Execute repair and replacement of data communication network components following OEM guidelines.
    - Troubleshoot faults within data communication networks based on OEM protocols.
    - Analyze and assess CAN network messages and integrity.
    - Utilize an oscilloscope to identify noise on the CAN bus network.
    - Analyze and graph live data, or interpret recent trace file data.
    - Perform root cause analysis of ZEB subsystems using fault data.

126. Control Systems:
    - Implement OEM guidelines for repairing and replacing control system components.
    - Diagnose control system faults in line with OEM troubleshooting procedures.
    - Interpret OEM schematics to identify control system faults.

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| | - Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 144. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>145. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>146. Electrical Theory Application:<br>- Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>147. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>148. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>149. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>150. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>151. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>152. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>153. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>154. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |

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| OSHA Basic Safety | 99. Understand OSHA Regulations: Gain familiarity with the Occupational Safety and Health Administration (OSHA) standards and their significance in the workplace.<br><br>100. Identify Focus Four Hazards: Recognize and evaluate the four primary hazards—fall, electrical, struck-by, and caught-in/between hazards—that pose risks in various work environments.<br><br>101. Assess Health Hazards: Identify common health hazards present in the workplace and understand their potential impacts on worker safety.<br><br>102. Implement Personal Protection Measures: Learn the importance of Personal Protective Equipment (PPE) and how to select and use it effectively to mitigate risks.<br><br>103. Utilize Hand and Power Tools Safely: Understand safe practices for the operation and maintenance of hand and power tools to prevent accidents and injuries.<br><br>104. Navigate Stairways and Ladders: Recognize safe usage and best practices for stairways and ladders to reduce the risk of falls and injuries.<br><br>105. Communicate Hazards Effectively: Learn about hazard communication and the Globally Harmonized System (GHS) for the proper labeling and handling of hazardous materials. |
| ZEB/ZEV Familiarization | 211. Introduction to ZEB<br>- Identify the introduction dates of battery electric and hybrid vehicles.<br>- Describe the principles of operation and major components of Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Compare ZEBs with traditional buses (hybrid, clean diesel, CNG) regarding fueling and propulsion characteristics.<br>- Explain the environmental benefits and capital investments in ZEB technologies.<br><br>212. Energy Storage System (ESS)<br>- Explain the purpose and major subcomponents of an ESS, including battery thermal management.<br>- Differentiate ESS design from low-voltage battery systems.<br>- Identify current ESS battery chemistries.<br>- Understand how capacitors function and compare to batteries.<br>- Identify voltage ranges for BEBs and HFCBs, noting advantages and disadvantages.<br>- Explain the need for thermal management in ESS and associated equipment.<br>- Describe the functions of ESS conductors, junction boxes, and fuse boxes.<br><br>213. High Voltage Distribution<br>- Explain the design and function of AC and DC high-voltage cables.<br>- Describe shielding functions on high-voltage cables.<br>- Understand the role of contactors and electrical switching devices in ZEBs.<br>- Explain the purpose of bus bars and distribution blocks.<br>- Describe insulation testing and its relationship with reference points.<br>- Explain the correlation between AWG wire gauges and ratings.<br><br>214. Grounding and Bonding<br>- Differentiate between grounding and bonding points and identify them.<br><br>215. High-Voltage Junction Box (HVJB)<br>- Describe the purpose and benefits of an HVJB and its subcomponents.<br><br>216. Traction Motors<br>- Explain the function of AC induction motors and regenerative braking.<br>- Discuss the need for cooling systems in traction motors.<br><br>217. Power Electronics<br>- Understand AC/DC characteristics and advantages of AC power in ZEBs.<br>- Explain the roles of inverters, including the difference between auxiliary and traction motor inverters.<br>- Discuss the purpose of variable frequency drives (VFDs) and cooling needs for electronic components.<br><br>218. Accessory Power (DC–DC) |

- Describe the function of DC–DC converters and examples of differing DC voltages needed in ZEBs.

219. Accessory Motors
    - Explain the need for motor-driven accessories and identify examples in ZEBs.
    - Discuss the power sources for electrically driven motors, including HV vs. LV and AC vs. DC considerations.

220. Thermal Management Systems
    - Explain the necessity of HVAC systems and their differences from ZEB thermal management systems.
    - Describe the function of coolant loops and their integration with HVAC systems.
    - Discuss auxiliary heaters in relation to propulsion and battery thermal management.

221. Charging Systems
    - Plug-in (Conductive)
        i. Describe functions of manual, plug-in charge connectors and charger–vehicle communication.
        ii. Identify relevant SAE standards and typical charging times.
        iii. Discuss the advantages and disadvantages of plug-in chargers and smart charging concepts.

    - Overhead (Conductive)
        i. Describe overhead pantograph charging methods, typical charging times, and applicable SAE standards.
        ii. Explain advantages and disadvantages related to overhead charging systems.

    - Inductive Charging
        i. Define inductive charging.
        ii. Describe typical charging times.
        iii. Explain advantages and disadvantages.
        iv. Identify SAE standard J-2954/2.

222. Data Communication Networks
    - Describe controller area network (CAN) protocols and standards.
    - Identify CAN components:
        i. Explain terminating resistors.
        ii. Explain gateways.
        iii. Explain shielding on data cables.
    - Identify subsystems using CAN communication.
    - Explain J1939 and data acquisition methods.
    - Compare SAE, IEEE, and proprietary data.
    - Explain communication between the charger and the bus.

223. Multiplexing (MUX)
    - Describe multiplexing protocols and standards.
    - Identify MUX network components.
    - Identify subsystems using MUX communication.
    - Explain J1213/1 and the “Glossary of Vehicle Networks for Multiplexing and Data Communications.”

224. Telematics
    - Describe vehicle telemetry system operation.
    - Explain the function of gateways.
    - Explain shielding on data cables.
    - Explain communication with the vehicle’s 12/24 V system through multiplexing.

225. Hydrogen Fuel Cell Bus Overview
    - Identify differences and similarities between Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).
    - Describe HFCB operation and fuel cell function.
    - Define major subsystems unique to HFCBs:
        i. Hydrogen system
        ii. Air intake system

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| | iii. Exhaust system<br>iv. Cooling system<br>v. System interfaces<br>vi. High-voltage system<br>vii. Low-voltage system<br>viii. Diagnostic system<br>- Define major safety components unique to HFCBs.<br>- Explain safety systems and strategies. |
| DVOM and Specialized Measuring Equipment For ZEVs | 1. Demonstrate best practices for using diagnostic tools including DVOM, Megohmmeter, Milliohmmeter, and Oscilloscope.<br>2. Understand the capabilities of multimeters in vehicle electrical systems.<br>3. Enhance accuracy in diagnosing electrical repairs to minimize downtime and improve repair quality.<br>4. Convert meter readings into specified service information values accurately.<br>5. Explore advanced testing equipment such as proving units, insulation testers, and resistance meters.<br>6. Select appropriate meters and measurement tools for specific tasks, ensuring safety and precision.<br>105. Apply safety practices when using meters.<br>106. Perform Live-Dead-Live testing on zero-emission vehicles.<br>107. Compare automotive multimeters' features and functions in practical applications.<br>108. Implement recommended practices for high-voltage measurement tools and techniques.<br>109. Diagnose and repair electrical faults effectively.<br>110. Conduct measurements and testing on high-voltage systems while using proper PPE.<br>111. Identify and apply the latest safety information to zero-emission bus (ZEB) systems. |
| HV Awareness Level 1 | 113. Identify electrical hazards and understand the potential injuries they can cause.<br>114. Differentiate between the roles of Aware, Qualified, and Authorized personnel in high-voltage environments.<br>115. Recognize visual cues that indicate hazardous voltage presence.<br>116. Utilize the Emergency Response Guide for bus operations and learn to disable high-voltage systems in emergencies.<br>117. Implement strategies to prevent electrical accidents and maintain a safe working environment.<br>118. Understand the various roles and responsibilities in Zero Emission Bus (ZEB) environments.<br>119. Improve response to potential dangers by recognizing visual signs of electrical hazards.<br>120. Interpret OSHA 1910 principles and the latest NFPA 70E standards for electrical safety in the workplace. |
| HV Awareness Level 2 | 141. Identify and describe the operations and functions of critical high-voltage components in Zero Emission Buses (ZEBs).<br>142. Explain the conversion process of electrical energy into mechanical energy for vehicle propulsion.<br>143. Differentiate between various vehicle safety systems utilized in ZEBs.<br>144. Describe high-voltage systems and outline the necessary safety measures for working with them.<br>145. Evaluate the purpose, capabilities, and ratings of Personal Protective Equipment (PPE) used in high-voltage operations.<br>146. Recall the concepts of Restricted, Limited, and Arc Flash boundaries and their role in protecting personnel from electrical hazards.<br>147. Explain how Lockout/Tagout (LOTO) procedures and testing for the absence of voltage contribute to creating a safe work environment.<br>148. Demonstrate practical knowledge of Lockout/Tagout procedures and absence of voltage testing.<br>149. Identify and explain the functions of key high-voltage components essential for effective diagnostics and repair.<br>150. Describe the ratings of PPE and their specific applications in high-voltage tasks. |
| ZEB/ZEV Safety 100 (Introduction to ZEB/ZEV Safety) | 127. Understand High Voltage (HV) Concepts:<br>- Define HV and distinguish between high voltage and low voltage in transit applications.<br>- Identify areas in Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where HV is present.<br><br>128. Recognize Safety Hazards:<br>- Describe the effects of electric current on the human body at various levels (50 to 150 mA, 1 to 4.3 amps, and 10 amps). |

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| | - Define arc flash, shock hazards, thermal runaway, and conditions that lead to these hazards.<br><br>129. Workplace Safety Regulations:<br>- Explain relevant workplace safety regulations (e.g., NFPA 70E, OSHA 1910) and their significance in HV systems and Zero-Emission Buses (ZEBs).<br>- Describe the importance of orange cables and looming.<br><br>130. De-energization and Safety Procedures:<br>- Detail procedures for deenergizing ZEBs and verifying zero voltage per OEM guidelines.<br>- Define lockout/tagout (LOTO) and battery lockout/tagout (BLOTO) procedures.<br><br>131. Equipment and Accident Protocols:<br>- Explain safety protocols for roof access, fall protection, and using jacking/lifting equipment on ZEBs.<br>- Describe accident and incident response protocols for key personnel, differentiating between technician and operator procedures.<br><br>132. Onboard Safety Equipment:<br>- Compare HV and low voltage disconnects and the significance of HV isolation detection.<br>- Explain the functions of high-voltage interlock loops, disconnects, and various safety components (e.g., pressure relief devices, gauges).<br><br>133. Personal Protective Equipment (PPE):<br>- Identify OEM high-voltage PPE requirements and conditions requiring PPE when working on ZEBs.<br>- Detail types of PPE necessary for high-voltage work and the importance of maintaining and inspecting this equipment.<br><br>134. Use of Insulated Tools:<br>- Identify common insulated tools and recognize unsafe insulated tools.<br>- Explain the necessity of insulated tools for various tasks, including maintenance and emergency response.<br><br>135. Emergency Preparedness:<br>- Outline the need for first aid kits and defibrillators in high-voltage applications. |
| First Response | 211. Identify general areas on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB) where high voltage (HV) is present.<br>212. Understand the physiological impacts of high voltage exposure on the human body at various current levels (50-150 mA, 1-4.3 amps, and 10 amps).<br>213. Define key electrical safety concepts including arc flash, shock hazard, and their potential for causing injuries, alongside the conditions that lead to these hazards.<br>214. Explain thermal runaway and its possible consequences in high voltage systems.<br>215. Describe relevant workplace safety regulations for high voltage systems and zero-emission buses (ZEBs), focusing on NFPA 70E and OSHA 1910.<br>216. Recognize the significance of orange cables and looming in identifying high voltage pathways.<br>217. Outline emergency towing and extraction procedures, including securement points.<br>218. Identify components necessary for high voltage isolation.<br>219. Locate passenger emergency egress areas on BEBs and HFCBs.<br>220. Describe procedures for extinguishing vehicle fires and managing battery thermal events.<br>221. Explain post-incident isolation procedures for high voltage systems.<br>222. Outline basic accident and incident protocols for key personnel.<br>223. Discuss special requirements for safely using jacking and lifting equipment on zero-emission buses.<br>224. Identify various onboard safety equipment and their locations, including high and low voltage disconnects, system fault indicators, and emergency disconnects.<br>225. Demonstrate the ability to interpret the NFPA-mandated Emergency Response Guide (ERG). |

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| Contact Release | 99. Understand the purpose and significance of Contact Release in high-voltage environments.<br>100. Identify the primary goals for successfully rescuing a person unable to self-release from an electrical source.<br>101. Recognize the characteristics and conditions indicative of a person requiring rescue.<br>102. Explore alternative tools for performing a Contact Release when a rescue hook is not available.<br>103. Memorize and outline the three critical steps necessary for executing a successful rescue.<br>104. Demonstrate the practical skills required to perform a Contact Release.<br>105. Identify essential skills for effectively responding to electrical accidents, reducing injury severity, and ensuring a safe rescue. |
| ZEB/ZEV Maintenance Overview (ZEB/ZEB Maintenance 100) | 29. Maintenance Intervals and General Tasks:<br>- Locate OEM documentation related to maintenance intervals and required tasks.<br>- Describe and perform common preventive maintenance subsystem inspections.<br>- Access ZEB service documentation, service and parts manuals, and integration guides effectively.<br>- Read and interpret schematics and technical drawings.<br>- Execute warranty claim procedures, if applicable.<br>- Establish contact with OEM customer service for support and inquiries.<br><br>30. Special Equipment and Procedures:<br>- Identify and utilize unique service tools and technical information specific to Zero Emission Buses (ZEB).<br>- Specify the types of digital multimeters required for ZEB applications.<br>- Understand and execute special towing and service line procedures for ZEBs, if applicable.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Explain the distinctions between grounding and bonding, and their significance.<br>- Compare maintenance inspection practices for internal combustion engine (ICE) vehicles and zero emission vehicles (buses). |
| ZEB/ZEV Electrical Theory | 99. Understand Electrical Principles:<br>- Examine and apply the fundamental laws of electricity, including Ohm's Law, Watt's Law, Kirchhoff's Laws, Faraday's Law, Lenz's Law, Coulomb's Law, Gauss's Law, as well as the distinctions between conventional and electron current.<br>- Utilize right-hand rules and the "ELI the ICE Man" concept to analyze voltage and current phase relationships in inductive and capacitive circuits.<br><br>100. Analyze Voltage Mathematics:<br>- Differentiate between series and parallel circuits and perform related voltage calculations.<br><br>101. Convert Power Ratings:<br>- Convert horsepower ratings to kilowatt ratings.<br><br>102. Explore Electrical Waveforms:<br>- Explain the various electrical waveforms relevant to zero energy building (ZEB) applications.<br><br>103. Distinguish Between Power Metrics:<br>- Differentiate between kilowatt and kilowatt-hour and explain associated energy values.<br><br>104. Utilize Testing Equipment:<br>- Demonstrate skill in using digital multimeters and other electrical testing equipment, including standard functions (voltage, resistance, current, continuity) and advanced functions (insulation, frequency, wave measurement).<br>- Understand measurement symbols, equipment specifications, and the appropriate use of testing instruments for different applications, including accessories like clamp-on ammeters and thermal testers.<br><br>105. Energy Characteristics of Battery Chemistries:<br>- Describe the energy characteristics of various battery chemistries including lithium-ion (specifying NCA, NMC, LMO, LTO, LFP), lead-acid (AGM), and nickel-metal-hydride (NMH).<br>- For each chemistry, explain configuration, nominal cell voltage, amp-hour rating, and energy ratings. |

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| Introduction to Troubleshooting | 239. Understand and utilize OEM documentation, schematics, and troubleshooting resources effectively.<br>240. Develop problem-solving strategies and critical thinking skills essential for technical diagnostics.<br>241. Apply the four steps of troubleshooting to systematically resolve issues.<br>242. Conduct root cause analysis to identify underlying problems.<br>243. Implement the Kepner-Tregoe method for structured decision-making in troubleshooting.<br>244. Utilize the IDEAL framework and KISS methodology for effective problem-solving.<br>245. Master logic and elimination methods in diagnosing vehicle issues.<br>246. Explore and assess vehicle subsystems and their potential failures.<br>247. Diagnose component failures through systematic testing and analysis.<br>248. Employ decision matrices and SWOT analysis for troubleshooting evaluation.<br>249. Conduct thorough component and electrical testing to confirm failures.<br>250. Measure performance to ensure effective diagnostics.<br>251. Use diagnostic tools and utilities for comprehensive troubleshooting.<br>252. Identify and analyze software components and potential issues.<br>253. Analyze logs and fault data to inform troubleshooting processes.<br>254. Tackle complex and uncommon technical issues effectively.<br>255. Document diagnostic processes and communicate findings clearly in maintenance reports. |
| ZEB/ZEV Safety Principles (ZEB/ZEV Safety 200) | 71. General Safety Procedures<br>- Identify and differentiate between high voltage (HV) and low voltage (LV) areas and cables on Battery Electric Buses (BEB) and Hydrogen Fuel Cell Buses (HFCB).<br>- Execute lockout/tagout procedures for LV and HV systems per Original Equipment Manufacturer (OEM) protocols.<br>- Demonstrate methods to de-energize a Zero Emission Bus (ZEB) and confirm zero voltage.<br>- Interpret key information from Safety Data Sheets (SDS) related to first aid, battery chemistry, energy density, and emergency procedures.<br><br>72. Responder Information and Safety Protocols<br>- Demonstrate roof access and fall protection procedures.<br>- Explain special jacking and lifting requirements for ZEBs.<br>- Perform essential accident and incident protocols for ZEB personnel, including energy isolation and post-recovery procedures.<br>- Check the high-pressure hydrogen safety system for Hydrogen Fuel Cell Buses (HFBC).<br><br>73. Onboard Safety Equipment<br>- Locate and describe the operation of HV and LV disconnects and high-voltage disconnect switches.<br>- Differentiate between measured and calculated high-voltage isolation status.<br>- Identify subsystems utilizing high-voltage interlock (HVIL) and describe their operations.<br>- Locate and explain the function of hydrogen overpressure devices.<br><br>74. Personal Protective Equipment (PPE)<br>- Identify and validate electrical meters and PPE suitable for HV applications.<br>- Ensure proper inspection and functionality of meters, leads, and PPE, including performing live testing according to agency protocols.<br>- Establish safe working boundaries in HV areas and demonstrate the correct use of various HV PPE.<br>- Explain cleaning procedures for arc flash-related PPE and perform inspections on insulated rubber mats and shepherd's hooks.<br><br>75. Insulated Tools Use<br>- Identify scenarios requiring insulated tools and verify their operational integrity.<br>- Demonstrate proper usage of insulated tools during work tasks. |

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| ZEB/ZEV Theory of Operation (ZEB/ZEV Subsystems 200) | 225. Energy Storage Systems (ESS)<br>- Identify and describe the location and operation of major ESS components, including battery packs, capacitors, conductors, junctions, and fuse boxes.<br>- Explain energy usage in ESS and the procedures for component removal and replacement according to regulations and standards.<br>- Understand the purpose of load-shedding as the State of Charge (SOC) drops and demonstrate the ability to use manufacturer-specific schematics.<br>- Describe the characteristics and configuration of ESS, including string controllers and battery management systems, and ensure the integrity of insulation properties.<br><br>226. High-Voltage Distribution<br>- Locate and differentiate among high-voltage (HV) and low-voltage (LV) cables, contactors, and relays.<br>- Explain the roles of fuses, busbars, and circuit breakers in electrical circuits, and perform correct insulation testing procedures.<br>- Describe the operation of a Battery Distribution Unit (BDU) and the purpose of relays for isolation in HV and LV systems.<br><br>227. High-Voltage Junction Box (HVJB)<br>- Understand electrical enclosure ratings and their implications for personnel and equipment safety.<br>- Identify components within the HVJB, including repairable and replaceable parts, and trace circuits using manufacturer-specific schematics.<br><br>228. Traction Motors/Generators<br>- Analyze the subcomponents of traction inverters and illustrate the operation of AC induction motors, including magnetic field rotation and winding configurations (Wye and Delta).<br>- Explain the operation of traction motors during regenerative braking and the generation of energy in this process.<br>- Discuss the role and operation of fuel cell inductors and transmissions in zero-emission buses (ZEB).<br><br>229. Power Electronics<br>- Describe the functions and subcomponents of variable frequency drives (VFDs) and differentiate them from traction inverters.<br>- Illustrate coolant flow in inverters and power electronic systems, and explain their normal operating ranges.<br>- Understand the DC-to-AC conversion process for propulsion and AC-to-DC conversion for regenerative braking and battery recharging.<br><br>230. Power Supply and DC-DC Converters<br>- Understand the function and operation of DC–DC converters in transitioning power from high-voltage (HV) to low-voltage (LV).<br>- Recognize when DC–DC converters are active or inactive and identify standard operating ranges of LV subsystems.<br>- List components that utilize LV power specific to Zero Emission Buses (ZEBs).<br>- Explain the role of an LV battery equalizer.<br><br>231. Auxiliary Drive Motors<br>- Identify and describe the operation of three motor-driven accessories in ZEBs and determine their power source (HV or LV).<br>- Utilize OEM schematics to pinpoint the electrical sources for these motors.<br><br>232. Thermal Management<br>- Differentiate between the battery coolant loop and the electronics coolant loop within the Battery Thermal Management System (BTMS).<br>- Describe the BTMS subcomponents and how it regulates temperature for the Energy Storage System (ESS).<br>- Understand operating temperatures for lithium-ion batteries and the function of a battery chiller.<br><br>233. HVAC Systems<br>- Compare passenger heating and cooling systems in ZEBs and Internal Combustion Engine (ICE) buses. |

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| | - Detail the HVAC components and explain the operation and purpose of the heat pump.<br><br>234. Auxiliary Heating Systems<br>- Describe the operation theory of both diesel-fired and electric auxiliary heating systems and locate their subcomponents.<br>- Assess the advantages and disadvantages of each auxiliary heating system type.<br><br>235. Coolant Loops for Hydrogen Fuel Cell Buses (HFCB)<br>- Explain the operation and components of main and auxiliary coolant loops in HFCBs.<br><br>236. Battery Electric Bus (BEB) Charging<br>- Describe intelligent charging methods and their pros and cons, outline safety precautions for charging equipment, and distinguish between charger-related and bus-related faults.<br>- Understand charger connection/disconnection procedures and identify SAE charging standards and their interface circuitry.<br><br>237. Data Communication Networks<br>- Explain the software and diagnostic connectors for Controller Area Networks (CAN) and identify subsystems using CAN communication.<br>- Describe CAN signals, verify network connections, and explain the difference between CAN and CAN flexible data, including the significance of baud rate.<br><br>238. Multiplexing (MUX)<br>- Identify MUX signals interface connectors and components, understand the integration of MUX and CAN networks, and recognize Parameter Group Numbers (PGN) and Suspect Parameter Numbers (SPN) for diagnostics.<br><br>239. Telematics<br>- Discuss accessible data from the telematics subsystem and methods for accessing telemetry data.<br>- Explain the management of ZEBs using telemetry data and how to capture and analyze trace files, along with the functions of telematics modules.<br><br>240. Fuel Cell Basics<br>- Explain fuel cell operation and the chemical reactions involved, the use of electrical output for charging ESS batteries, and understand State of Charge (SOC) requirements and fueling procedures for Fuel Cell Buses (FCB).<br>- Describe the system architecture of FCBs. |
| OEM Maintenance and Repair | 127. General ZEB Maintenance:<br>- Locate and utilize special equipment and inspection procedures per OEM recommendations.<br>- Prepare vehicles for maintenance by isolating contactors, ensuring disconnections, and following LOTO procedures.<br>- Understand the purpose of service tools and OEM service information.<br>- Use a digital multimeter specific to high-voltage ZEB applications.<br>- Describe special towing and unique service line procedures for ZEBs.<br>- Conduct basic inspections and maintenance of AC and DC high-voltage cables.<br>- Perform basic insulation tests and analyze results.<br>- Diagnose faults and trace data to identify root causes of failures.<br><br>128. Maintenance Inspection Procedures:<br>- Implement correct OEM inspection procedures for the driver's area, pneumatic systems, and passenger compartments.<br>- Assess OEM inspection procedures for fire suppression systems, HVAC subsystems, and auxiliary heating systems specific to ZEBs.<br>- Follow OEM guidelines for inspecting and lubricating underbody equipment, traction motors, suspension, and steering systems.<br>- Conduct inspections of wheels, brakes, differentials, drive axles, rooftop areas, energy storage systems, high-voltage systems, telematics, and vehicle body components.<br>- Analyze historical telemetry data for performance insights. |

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| | 129. Power Inverter/Power Electronics:<br>- Adhere to OEM guidelines for the removal and replacement of power inverter and power electronics components.<br>- Troubleshoot power inverter faults in accordance with OEM standards.<br>- Measure, interpret, and record power inverter resistance values.<br>- Program inverters where applicable and diagnose the need for reprogramming or replacement.<br><br>130. Energy Storage Systems (ESS):<br>- Follow OEM guidelines for the removal and replacement (R&R) of ESS components.<br>- Safely troubleshoot ESS faults in accordance with OEM protocols.<br>- Identify and repair ESS thermal management system faults.<br>- Diagnose control system faults, including contactors and pre-charge resistors.<br>- Perform battery balancing and string equalization using proper procedures.<br><br>131. Power Generation/Charging:<br>- Adhere to OEM guidelines for R&R of power generation and charging components.<br>- Troubleshoot power generation and charging faults according to OEM standards.<br>- Inspect and repair all charging interfaces for damage or faults.<br>- Differentiate between charger and bus-related faults and perform necessary repairs.<br>- Diagnose ground fault monitoring functionality and conduct troubleshooting and repairs.<br>- Test insulation resistance and determine deviations, repairing as needed.<br>- Assess isolation resistance values, identify discrepancies, and implement repairs.<br><br>132. High-Voltage Cables:<br>- Follow OEM guidelines for the R&R of high-voltage cables and bus bar components.<br>- Troubleshoot high-voltage cable and bus bar faults according to OEM standards.<br>- Determine the necessity for repairing or replacing high-voltage cabling and execute the required procedures.<br>- Build or repair high-voltage cables, including stripping insulation and crimping lugs.<br><br>133. Traction Motors:<br>- Understand and apply OEM guidelines for the repair and replacement of traction motor components.<br>- Troubleshoot traction motor faults in accordance with OEM standards.<br>- Conduct insulation and winding resistance tests on each motor phase.<br><br>134. Data Communication Networks:<br>- Execute repair and replacement of data communication network components following OEM guidelines.<br>- Troubleshoot faults within data communication networks based on OEM protocols.<br>- Analyze and assess CAN network messages and integrity.<br>- Utilize an oscilloscope to identify noise on the CAN bus network.<br>- Analyze and graph live data, or interpret recent trace file data.<br>- Perform root cause analysis of ZEB subsystems using fault data.<br><br>135. Control Systems:<br>- Implement OEM guidelines for repairing and replacing control system components.<br>- Diagnose control system faults in line with OEM troubleshooting procedures.<br>- Interpret OEM schematics to identify control system faults.<br>- Utilize ladder logic documents to troubleshoot control system issues when applicable. |
| Electrical System Diagnosis | 155. Interpret Electrical Schematics:<br>- Understand and analyze basic electrical schematics, one-line diagrams, and wiring diagrams, including wire and terminal identification.<br><br>156. Circuit Relation:<br>- Relate physical circuits to wiring diagrams and electrical schematics effectively.<br><br>157. Electrical Theory Application: |

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| | | - Apply principles of electrical theory to the troubleshooting process in Zero Emission Vehicles (ZEVs).<br><br>158. Troubleshooting Skills:<br>- Identify, analyze, and resolve electrical issues safely using established tools and techniques.<br><br>159. Measurement Proficiency:<br>- Utilize DVOMs, megohmmeters, milliohmmeters, oscilloscopes, and specialized equipment for accurate electrical measurements, including voltage, current, and resistance.<br><br>160. Component Testing:<br>- Identify signs of failure in various electrical components and perform appropriate tests on them.<br><br>161. Ladder Logic and Trouble Trees:<br>- Understand and interpret ladder-logic diagrams and utilize trouble trees for troubleshooting.<br><br>162. Circuit Construction and Diagnosis:<br>- Build or diagnose complex electrical circuits using provided components and schematics.<br><br>163. Troubleshooting Techniques:<br>- Apply various troubleshooting techniques such as half-splitting and voltage tracing to enhance diagnostic accuracy.<br><br>164. Testing Methodology:<br>- Describe effective testing methods to verify fixes after troubleshooting to minimize return rates.<br>165. Documentation and Communication:<br>- Accurately document diagnostic steps and communicate results clearly in maintenance reports. |