

Name _____

Date _____

Post-Course Assessment - Answers

1. **Circle** the correct answer. Which of the following are components are *different* between both traditional and battery electric buses?


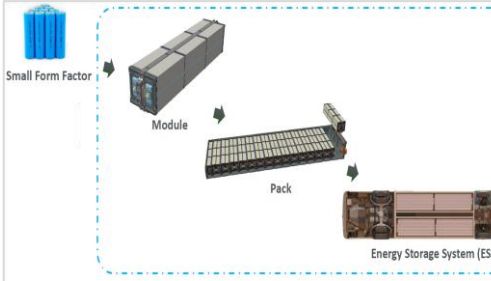
- a) Powertrain
- b) HV batteries and HV battery management systems
- c) Charging methods and equipment
- d) All of these are different between bus types
- e) None of these are different between bus types




Answer: D

2. **True or false.** Preventive maintenance is the act of performing a series of maintenance tasks/activities within a regularly scheduled period to prevent possible outcomes or vehicle failures.

TRUE

3. Use the table below to fill in the missing section of detail for the components:

Component	Function	Image
External (Manual) Charge Port	This port is used to connect the depot's installed charging equipment to the bus. This allows for controller area network [CAN] communication between the vehicle charge controller and the charging equipment.	
Energy Storage System (ESS)	A component comprised of the high voltage batteries that power the bus as well as various controllers. Small form factor cells comprise modules within the high voltage battery packs, and then multiple battery packs are connected to create strings. In a different way, think of the ESS as the equivalent to onboard fuel—whether	

	it be diesel, hydrogen or any other fuel cells.	
High Voltage Junction Box [HVJB]	Used to safely distribute the high voltage from the ESS to various high voltage components and subsystems found on the bus.	
DC/DC Converter	A liquid cooled component that used to change high voltage DC to low voltage DC ("step down" HV). These converters charge the low voltage batteries and supply low voltage power when the high voltage system is enabled.	
Electronic Controllers	Used throughout the bus to monitor and control the high voltage and low voltage power. They help ensure the safe operation of all subsystems on the bus.	

4. **Circle** the correct answer. Which of the following are components that are *similar* in both standard and battery electric buses?
- a) Air system and power steering
 - b) Axles
 - c) Low voltage 12V and 24 V systems
 - d) Grounding process
 - e) Multiplexing and I/O systems
 - f) Cooling systems
 - g) CAN systems and principles
 - h) Doors and ADA equipment
 - i) All are similar between bus types

Answer: I

5. Using the image below to answer the question: Which components in areas 4 and 5 have high voltage?

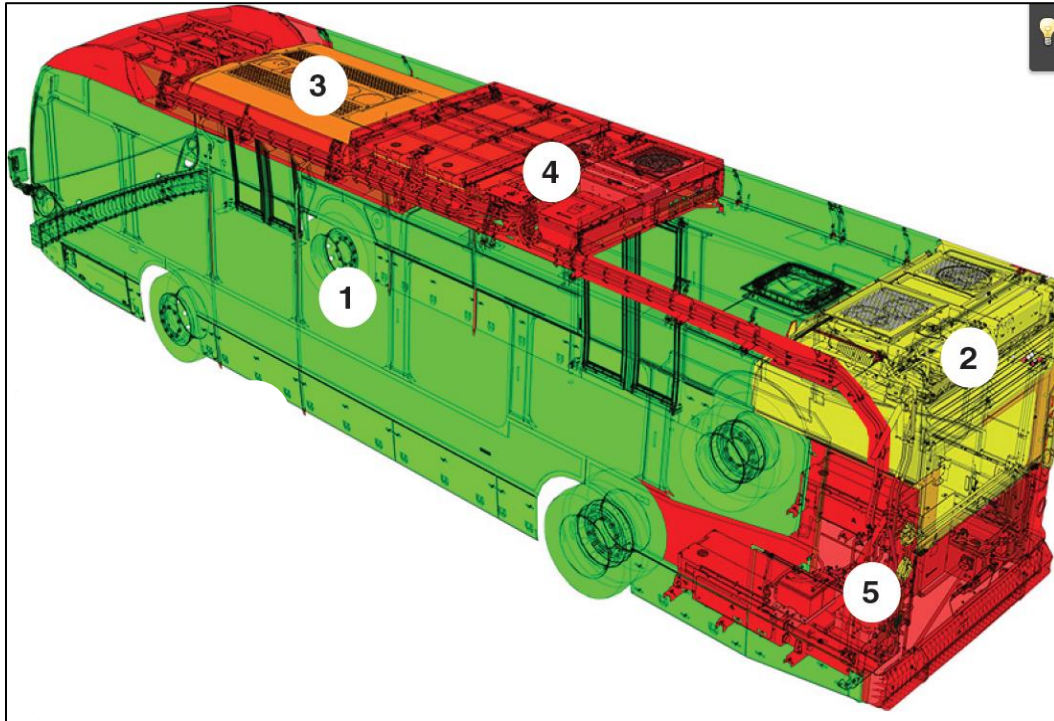
High risk:

COURSE: Battery Electric Bus Familiarization

Batteries, can be between 1 and 4 of them (this model). Located in engine bay and/or roof top or built-into the floor.

Junction Boxes. Bringing batteries together with devices like the inverter or an Accessories converter.

Pantograph rails (front of the bus). The area would be at full 750-volt DC potential.



6. Use the phrases from the word bank to fill in the blanks to describe the multiplexing system theoretically operates:

a) *Input, signal, other modules, act, output, other modules*

An **input** is received by a module (from a switch, sensor, etc.).

The input acts as a **signal** (of voltage or ground from a switch, sensor, etc.).

That module will then send a signal over the communication network to the **other modules**.

The other modules are programmed to **act** when they receive a particular command.

An **output** is sent as a signal (voltage or ground) from a module to a load or another device.

The process continues constantly; every module is constantly in communication with the **other modules**.

7. **Circle** the correct answer. Which of the following is not a type of diagnostic equipment?
- Powertrain dongle
 - NEXIQ interface tool
 - Laptop
 - All of these are diagnostic equipment

Answer: D

8. **True or false.** CAN systems are a type of serial communications protocol that allows electronic units to communicate and share essential vehicle control data and allows data to be packaged together, reducing the number of transmissions necessary.

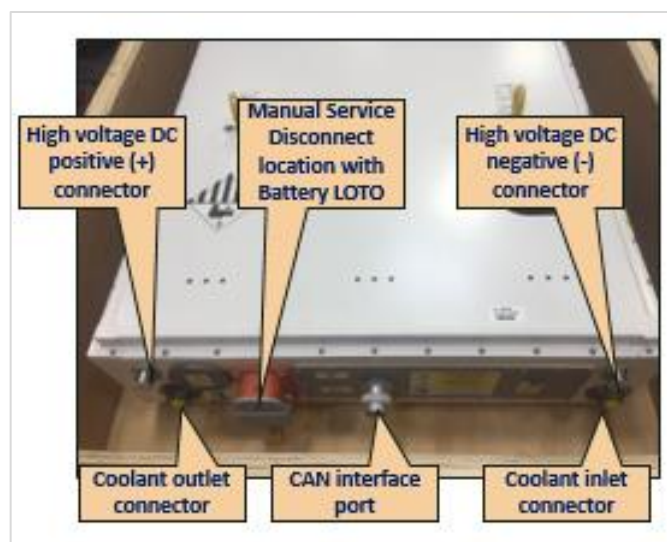
TRUE

9. **Circle** the correct answer. Which of the following is not a component of a BEB that utilizes a coolant loop/cooling management?
- DC/DC Converter
 - Battery Coolant loop
 - Power Electronics coolant loop
 - Coolant temperature sensors
 - Coolant loop filters
 - All of them utilize coolant loops/cooling management

Answer: F

10. Using the word bank provided, fill in the areas of an ESS battery module in the image below:

- High voltage positive (+) connector, Manual Service Disconnect location with battery LOTO, CAN interface port, Coolant inlet connector



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11. **Circle** the correct answer. Which of the following is the purpose of a battery thermal management system [BTMS]?
- A low voltage control safety feature
 - A device to prevent us from getting exposed to high voltage in the event of leakage in the batteries
 - Maintain the internal temperatures of the battery packs to prolong lifespan
 - A serial communication network that allows electronic units to share essential vehicle data

Answer: C

12. Use the phrases from the word bank to fill in the blanks to describe the process of power flow on a BEB:
- a) *ESS, AC waveform, never a positive and negative of the same phase at the same time, alternate, magnetic attraction, contactors, high voltage junction box [HVJB], traction motor*

BEBs however, will use the energy stored in the ESS to power a traction motor, which is connected to the drive axle.

In any instance where a subsystem was driven by an accessory belt on a diesel bus, an appropriately-sized electric motor is used to drive that accessory. The 3-phase inverters switch high voltage DC energy on and off to create an AC waveform.

Essentially, you are switching on—whether it be two positive phases, or two negative phases—but never a positive and negative of the same phase at the same time.

In order to turn the rotor inside the traction motor, power is supplied to the coils to generate a magnetic field in each. To continue the rotation of the rotor, the pattern needs to alternate.

An AC motor works by applying alternating current to stator windings, which produce a rotating magnetic field in the rotor. The rotor will then start to follow the rotating field and stator windings due to the magnetic attraction.

Starting off, after initial safety checks are performed by the controllers, the contactors inside the high voltage batteries are commanded closed to supply power to the high voltage system

High voltage power from the ESS is sent first to the high voltage junction box [HVJB] for distribution amongst the high voltage subsystems

From the HVJB, high voltage power is supplied to the traction motor and inverted to provide acceleration to move the bus bottom.

13. **True or false.** Always assume the system is safely *de-energized*.

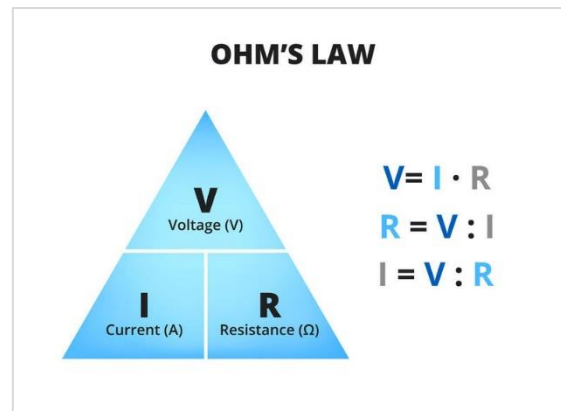
FALSE

14. **Circle** the correct answer. Which of the following is *not* true of the High Voltage Interlock Loop [HVIL]?

- When a failure is detected in this circuit **and** the parking brake is set, the vehicle controller will respond with an emergency high voltage shutdown to remove any potential high voltage exposure as quickly as possible
- You can disconnect the HVIL without switching off the battery disconnect switch first
- Troubleshooting this system will require that the vehicle be in a low voltage on mode of operation
- The HVIL is a system designed to prevent unexpected exposure to High Voltage – it is not intended as a way to isolate the High Voltage system. High Voltage isolation should always be accomplished via the LOTO process
- All are considerations of the HVIL safety features

Answer: B

15. **Circle** the correct answer. Based on the image in below, which of the following is the common formula for calculating **voltage through Ohm’s Law**?



- $I \times R$
- V^2/P
- P/I
- V/R

Answer: A

16. **True or false.** BEB battery packs will be well-encased and include locked/non-conductive covers, venting and are moisture proofed.

TRUE

17. **True or false.** You should work on an HV system by yourself because there is no need for a qualified second person to act as an observer and safety backup.

FALSE

18. What are some risks and considerations that can be associated with arc flashes?

- **Burns:** When an electric arc occurs, it generates immediate extreme temperature and increased risk of severe burns.
- The resulting explosion can cause fires and serious harm to equipment and people. The temperature of an arc flash may exceed 35,000 degrees Fahrenheit, which is capable of vaporizing metal and sending a blast of plasma and molten metal in all directions with extreme force.
- **Metal projections:** Metal explodes when an electric arc occurs and super-heated shrapnel can be projected in every direction.
- **Fall from Height:** In many installations, the HV batteries are mounted on the vehicle roof.
- **Concussive blasts** – an explosion that results in a blow to the head caused by the resulting force from an arc flash
- **Fall protection** - Human instinct is to *recoil* from an arc flash, which could cause a fall from a height of greater than ten feet [$>10'$]. That could mean fall-protection harnesses, and lanyards. It could mean ladders and work platforms. They are investments in keeping employees safe.

19. **Circle** the correct answer(s). What is a thermal runaway event?

- A sudden release of energy or undesired electric discharge the generated intense light and heat, radiating at supersonic speeds
- The electrical disconnect verification procedure(s) for a BEB
- The chance (high or low) that any hazard will actually cause someone harm
- A condition that typically occurs due to increased heat and temperature conditions within the battery packs, that is created when the heat generated within a battery exceeds the amount of heat dissipated to its surroundings.

Answer: D

20. **True or false.** High voltage risk can occur with anything over **50 volts**.

TRUE

21. Describe the options for testing and inspection rubber insulated gloves.

The “blow and fold” technique

- Users can roll gloves in their hands or inflate them manually to better expose imperfections and air leaks.
- Holes, perforations, tears, cuts, cracks, burn marks, air bubbles, encrusted or bonded material

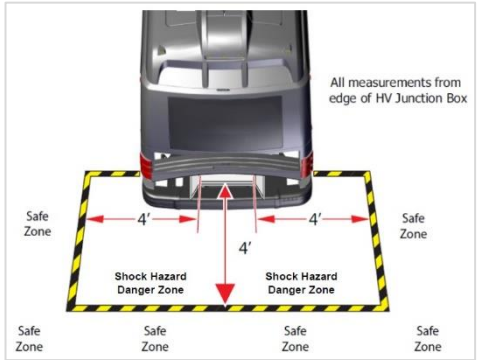

Use a specialized glove inflator. The glove is placed over top of it and inflates the glove. Then we can carefully inspect and hold the glove up to our face making sure it stays inflated, even bringing it close to our chin or cheek to feel if any air is escaping. However, **do not** stretch gloves beyond limits set by the manufacturer.


- Check for air leaks, by listening for escaping air or bringing gloves to your chin to feel the air escaping;
- A visual examination of the palm, back, fingers, wrist, and sleeve when gloves are inflated

Dielectric tests (sent to a lab):

- To make sure gloves maintain their insulating properties, dielectric testing by a recognized, qualified laboratory is required
- The date of dielectric testing must be logged or printed on each glove. This date will be stamped on the gloves when you first purchase them. After being tested a new tag on top (or date) will be added to show they have been retested

22. Use the table below to fill in the missing sections of detail for safety equipment:

Component	Function	Image
Safety Barricade	Barricades would be considered “a physical obstruction such as tapes, cones, or A-frame type wood or metal structures that provides a warning about, and limits access to, a hazardous area.” Anyone wandering nearby will find themselves with a physical obstruction preventing unauthorized access or from possible contact with any energized equipment or systems.	
Insulated Rescue Hook [shepard's hook]	A utility tool that acts as an extension pole for you or another person to safely move or remove someone who may have been injured or incapacitated by a source of HV or electrical hazards. The extended length of the hook allows using it to maneuver the incapacitated person without exposing themselves to the same electrical hazard.	

<p>Meters & Digital Multimeter [1000v Category III/600 Cat IV/10 Mega Ohm Impedance (or greater)]</p>	<p>A meter is any device that can be used to take measurements, and there are several that measure one specific unit:</p> <p>Ammeter – measures current</p> <p>Voltmeter – measures only voltage</p> <p>Ohmmeter- measures resistance; gives an actual resistance unit between two points</p> <p>Most meters will offer two options for resistance: continuity and ohmmeter (continuity in our case means that the points are electrically connected and a circuit exists)</p> <p>Megohmmeters- measures very large resistances</p>	
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23. **True or false.** It is critical that the safety observer (monitor/checker) wear the same PPE while in the same approach boundary as the person testing for the absence of voltage.

TRUE

24. Match the correct charging options to their definitions below:

- i. Plug-In or Depot Charging [AC Charger]
 - ii. DC Charger
 - iii. Overhead
 - iv. Inductive/wireless charging
1. **Plug-In or Depot Charging [AC Charger]**
 - v. A means of charging with a unit at the depot (agency). Initially depot charging was typically an AC charger that was used to replace the diesel fuel nozzle
 2. **DC Charger**
 - vi. Has the inverter in the converter [DC], so it will have a bigger cabinet and be more expensive (but that is fine with BEBs). The trade-off is that is that it can charge faster and requires less time to charge.
 3. **Overhead**

- vii. Done via overhead using a roof-mounted pantograph charging system. Overhead pantograph typically will incorporate power distribution box and a means of charging
- viii. Includes pantograph down or pantograph up styles, where the pantograph comes down and charges the bus. The on top of the bus will have rails to accept the power. Overhead chargers are typically pantograph up or down style. This charging method usually requires less battery capacity as charging more frequently on the route

4. **Inductive/wireless charging**

- ix. Done via electromagnetic induction, and is a relatively new emerging technology that has been gaining popularity
- x. technology consists of a wireless charging station in the ground (a pad) and with pads on the bus as well

25. **True or false.** Standard J2954-2 describes the method of depot charging utilizing smart charging capabilities.

FALSE

26. **Circle** the correct answer. Given a bus with a battery capacity of 360kWh and an effective charging power of 120 kW, what is the anticipated charge time?

- a. 4.6 hours
- b. 3 hours
- c. 4 hours
- d. 3.6 hours

Answer: B

27. **True or false.** The purpose of a switchgear is to transfer electrical energy from one electrical (AC) circuit to another circuit (even multiple) while either increasing or decreasing voltage.

FALSE

28. **True or false.** Standard J1772 describes the electrical and physical interfaces between the vehicle and supply equipment in a plug-in configuration to facilitate conductive charging.

TRUE

29. List three (3) safety precautions for charger maintenance.

- One of the most important things to remember is to disconnect all input and output sources and use proper caution before opening or working on any equipment.
 - It should be mentioned again that everything is infinitely safer if you know the equipment is off and you've verified the absence of voltage with the proper

measuring instrument. Everything that in the circuit if you are going to work on it at all needs to be “dead,” and that’s the safest way to work on it.

- Next are the DC link capacitors. These DC link capacitors can hold a charge after being disconnected from the grid and DC input. You want to make sure you verify that you wait the proper amount of time based off of what any of the OEMs recommend.
 - This can be anywhere from approximately 10 to 15 minutes (give or take) to make sure that the DC link capacitors have bleed down. This can actually become a shock hazard, or even an arc flash hazard depending on how they are integrated into the circuit.
- Another good reminder is that you need to remove your jewelry-any watches, rings or metal objects from your person. You don’t want to give any of the power an easy path to ground, or give an easy path towards ground through you. It becomes a shock hazard; it becomes an arc flash hazard so just make sure that you take off any jewelry.
- If you’re servicing any of the electronic components (and in this case more of the printed circuit boards), make sure you’re using an anti-static wristband. Make sure that you don’t accidentally discharge just a little bit of static electricity on any of these circuit boards, as they are controlling the high voltage at very strict tolerances.
- Be sure that all electrical connections and connectors are installed and properly torqued.
- To properly service any charging equipment, you will need certain PPE. This would include:
 - Arc flash suit
 - Arc flash face shield with a hard hat
 - A balaclava or arc flash hood
 - Safety glasses and earplugs or inserts
 - Rubber-insulated gloves with leather overlays
 - EH-rated safety shoes.
 - Use the proper PPE and equipment
 - Anti-static wrist strap