

# Module 1: Introduction Electrical Theory for Electric School Bus Workers

## Why should you know about electrical theory?

Electricity is all around us, and we use it everyday to light our homes, charge our phones, even cook our food and run our cars. Understanding electrical theory will help you be prepared to interact with and work on an electric school bus.

## Electricity Basics

### What is electricity?

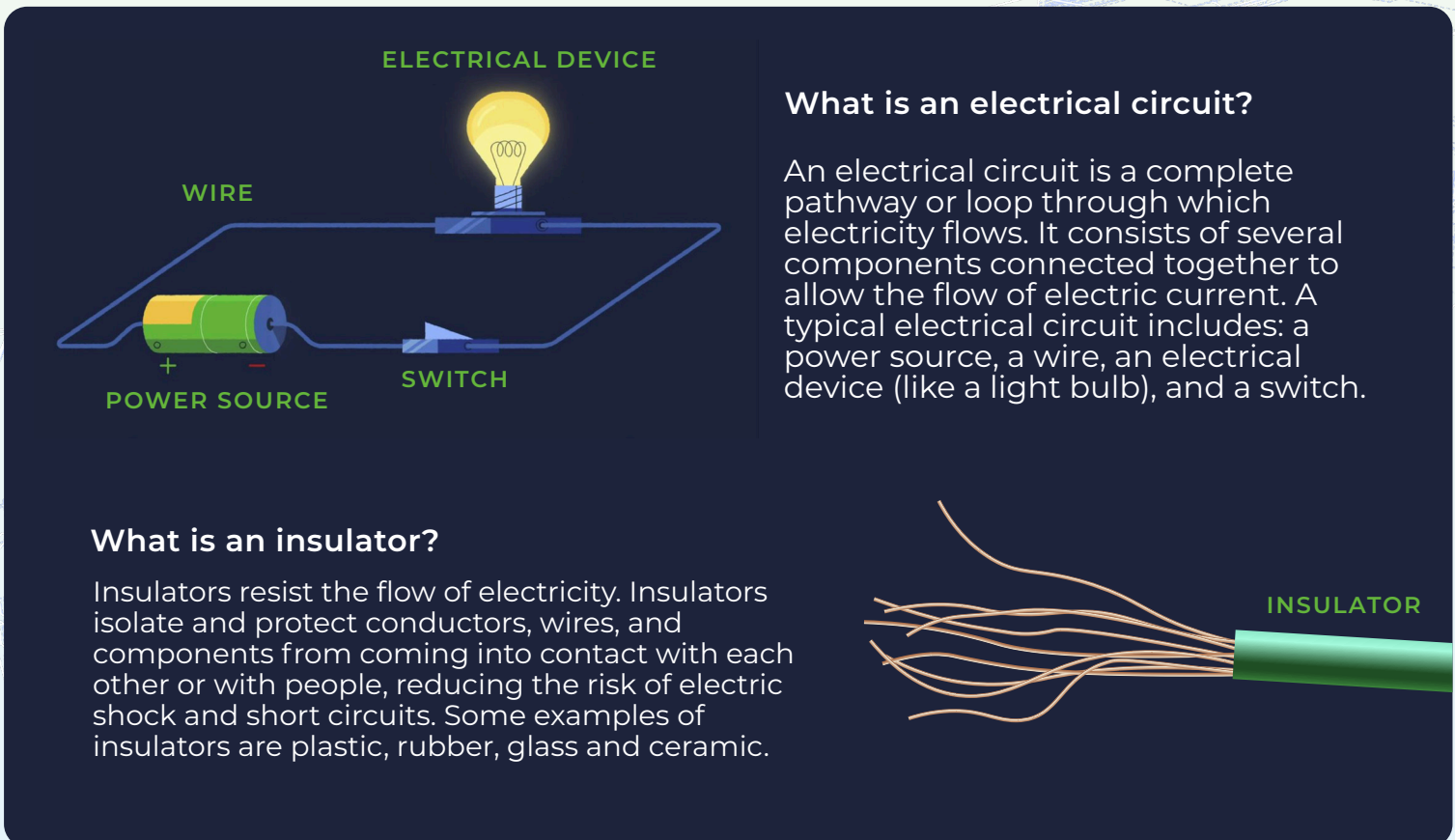
Electricity is a form of energy that results from the movement of tiny particles called electrons. These electrons carry a negative charge and are found in most materials, especially metals like copper and aluminum.

### What is a conductor?

A conductor is a material that allows electricity to flow through it easily. In other words, it's like a pathway that lets electric current pass without much resistance. Some examples of conductors are copper, aluminum, steel, brass, silver and gold. Most wires are made out of copper.

### How is electricity generated?

Electricity generation is the process of converting various forms of energy sources like water, wind, solar, natural gas, and others into electrical energy that we can use to power our everyday lives.



The diagram shows a complete electrical circuit on the left and a cross-section of an insulated wire on the right. The circuit includes a battery (power source), a switch, a wire, and a light bulb (electrical device). The wire is shown as a continuous loop connecting the battery, switch, and light bulb. The insulated wire shows multiple copper conductors bundled together and covered by a green plastic sheath (insulator).

ELECTRICAL DEVICE

WIRE

POWER SOURCE

SWITCH

What is an electrical circuit?

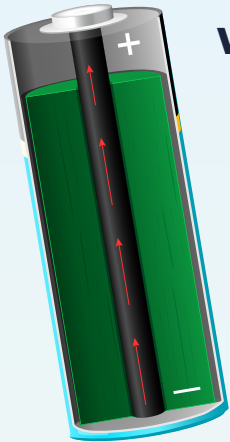
An electrical circuit is a complete pathway or loop through which electricity flows. It consists of several components connected together to allow the flow of electric current. A typical electrical circuit includes: a power source, a wire, an electrical device (like a light bulb), and a switch.

What is an insulator?

Insulators resist the flow of electricity. Insulators isolate and protect conductors, wires, and components from coming into contact with each other or with people, reducing the risk of electric shock and short circuits. Some examples of insulators are plastic, rubber, glass and ceramic.

INSULATOR

# Module 1: Introduction Electrical Theory for Electric School Bus Workers

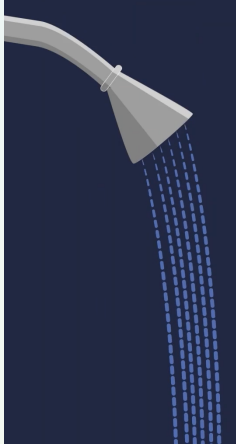


## What is a Battery? How is electricity stored in batteries?

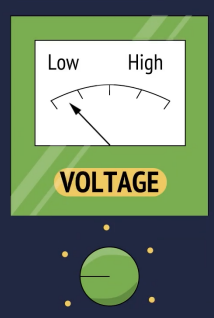
A battery is a device that stores chemical energy and converts it into electrical energy. It consists of one or more electrochemical cells that work together to produce a flow of electrons (electricity) when connected to an electrical circuit.

Inside a battery, there are chemicals (called electrolytes) and materials (such as metals) that react with each other to produce electrical energy. When you connect a battery to a device like a smartphone or an electric motor, the chemicals react with each other and generate electrons that flow through the wires and power the device.

## Fundamental Principles




**Voltage:**

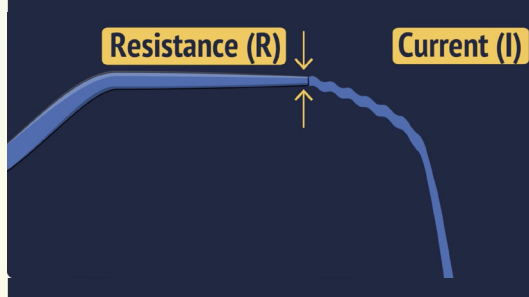


Voltage describes the pressure that pushes electricity. Voltage is what makes electricity move from one place to another, powering up devices and lights in our homes. "High voltage" or "low voltage," refers to how strong the push of electricity is, which affects how much power a device can handle or how far electricity can travel effectively.

**Current:**

Electric current is the movement of electric charge (typically electrons) through a conducting material, such as a wire. When we plug in a device or turn on a light, electrons start moving through the wires, carrying electrical energy to power the device.





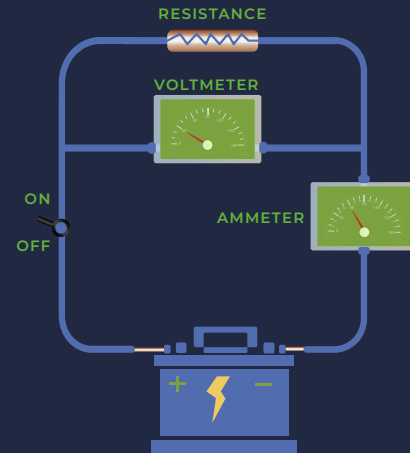
**Resistance:**

Resistance is the counteracting force for current flow or electricity. It keeps electricity from flowing freely. When electricity flows through a wire or a circuit, it encounters resistance, which is like obstacles in its path. These obstacles can slow down the flow of electricity. Resistance serves as the controlling force that allows us to make electricity work the way we need it to. Materials with low resistance allow electricity to flow through them easily, while materials with high resistance make it harder for electricity to pass through.

# Module 1: Introduction Electrical Theory for Electric School Bus Workers

## Ohm's Law:

Ohm's Law is a fundamental principle in electricity that describes how voltage, current, and resistance are related in an electrical circuit. Ohm's Law states that the electric current through a conductor between two points is directly proportional to the voltage across the two points. For example, if you increase the voltage, more current will flow through the circuit, assuming the resistance stays the same. Conversely, if you increase the resistance, less current will flow for a given voltage. Ohm's Law helps us understand and predict how electricity behaves in different circuits and is essential for designing and troubleshooting electrical systems.



## Electrical Energy:

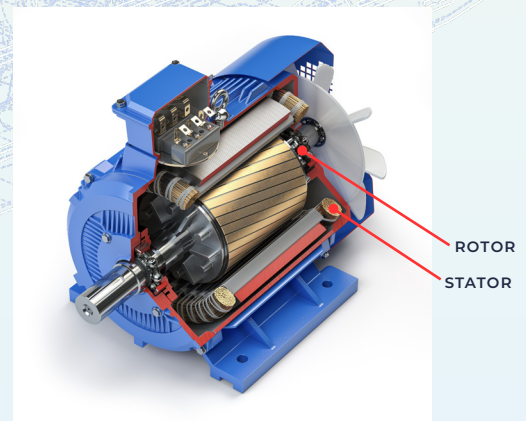
Electrical energy is the energy produced by the movement of electric charges, specifically electrons, through conductive materials like wires. Energy is measured in watt-hours (Wh) and kilowatt-hours (kWh), which represent the total amount of energy used or produced over a specific period.

## Electrical Power:

Power is the rate at which electrical energy is converted into other forms of energy, such as light, heat, or mechanical work. The amount of power a device uses depends on both the voltage (electrical pressure) and the current (flow of electricity) in a circuit. Understanding power ratings helps us choose appropriate devices for our needs and manage energy consumption efficiently. It's an important factor in electrical safety and designing systems that can handle the power demands without issues like overheating or overloading. Power is measured in watts (W), which indicate the rate of energy transfer or consumption at any given moment.

## What is an Electric Motor?

An electric motor is a device that uses electricity to create movement. It's like a magic box that turns electrical energy into mechanical energy, which makes things move. Imagine a hollow tube (the rotor) surrounded by a bunch of coils of wire (the stator). When you send electricity into these coils (through wires), they create a magnetic field that makes the rotor spin. The spinning rotor is connected to gears or wheels. When the rotor spins, it turns these gears or wheels, causing movement. Electric school buses have motors instead of engines.



# Module 1: Introduction Electrical Theory for Electric School Bus Workers

## Measurements of Electricity

### A Amperes

An ampere, often abbreviated as "amp," is a unit of measurement used to quantify electric current. It represents the rate of flow of electric charge through a conductor. An ampere measures the amount of electric charge passing through a point in a conductor per unit of time. Understanding amperes is crucial for safely designing and using electrical systems. Overloading a circuit with too much current can cause overheating, tripped circuit breakers, or even electrical fires.

### V Volts

Think of volts like the pressure in a water pipe. Higher pressure (volts) can push more water (electricity) through the pipe (circuit), while lower pressure (volts) results in less flow. Similarly, higher voltage can drive more electric current through a circuit. Volts are essential for understanding how electricity behaves and how electrical devices operate. Higher voltages can deliver more power but also require appropriate safety measures and insulation to prevent shocks or hazards.

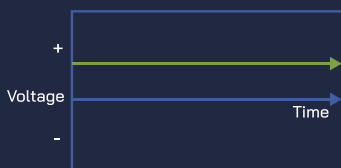
### W / kW Watts

A watt (W) is a unit of measurement used to quantify power. It represents the rate at which energy is used, transferred, or produced in an electrical system. Understanding watts helps us evaluate the energy efficiency and performance of electrical devices and systems. Higher wattage devices consume more electricity and may require more power to operate effectively. Electric school buses are rated in kilowatts (kW), which indicates the capacity to produce electrical power. Note: 1 kW = 1000 W.

### Wh Watt-hours

A watt-hour (Wh) is a unit of measurement used to quantify the amount of energy consumed or produced over a period of time. It represents the amount of energy used by a device that operates at a constant power of one watt for one hour. For example: if you have a light bulb that consumes 10 watts of power and you leave it on for one hour, it will consume 10 watt-hours of energy. Watt-hours help us understand and quantify the energy usage or capacity of electrical devices, appliances, batteries, and power systems. It's a crucial concept for managing electricity usage, estimating costs, and evaluating the performance of energy storage solutions.

### DIRECT CURRENT (DC)



The direction of the current of the voltage is always constant.

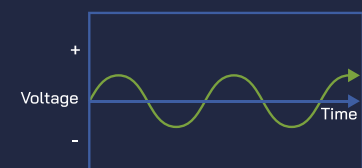
### What is direct current?

Direct current (DC) is a type of electrical current where the flow of electric charge travels continuously in one direction through a conductor. In a DC circuit, electric charge flows steadily from a positive terminal to a negative terminal. The batteries in electric school buses provide direct current.

### What is alternating current?

Alternating current (AC) is a type of electrical current where the direction of electric charge periodically changes back and forth. AC motors are highly efficient, converting a high percentage of electrical energy into mechanical motion, which helps maximize the range of electric vehicles. AC motors can provide strong torque (rotational force) across a range of speeds, resulting in smooth and responsive acceleration. AC motors can also function as generators during braking, capturing energy from braking and storing it in the battery. This process is called regenerative braking.

### ALTERNATING CURRENT (AC)

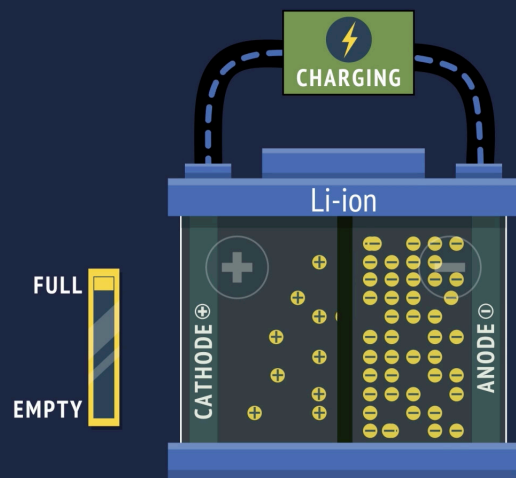


The direction of the current is always switched periodically, and the voltage is also switched.

# Module 1: Introduction Electrical Theory for Electric School Bus Workers

## What is an inverter?

In electric school buses, an inverter is a critical component that converts the DC (direct current) stored in the vehicle's battery into AC (alternating current) to power the electric motor that drives the wheels. Electric motors in EVs operate on AC electricity. However, the energy stored in batteries is in the form of DC electricity. Therefore, an inverter is needed to convert the DC electricity from the battery into the AC electricity required by the electric motor. Inverters play a crucial role in optimizing the performance and efficiency of electric motors in electric school buses. They enable smooth and precise control of the electric motor's speed and torque, which contributes to the overall driving experience and vehicle responsiveness. Inverters also support regenerative braking, a feature where the electric motor acts as a generator to recharge the battery during braking, improving energy efficiency and extending driving range.



## How does charging work?

Charging is the process of refueling electric school buses by connecting them to an electrical power source. To charge an electric vehicle, you typically plug the charging cable into the vehicle's charging port and then connect the other end to the charging station. The charging station communicates with the vehicle to provide the correct amount and type of electrical power needed for charging. Once connected, the vehicle's onboard charger converts the incoming AC power to DC power to charge the battery.

## What do I need to know about operating an electric school bus in different weather conditions?

The battery range performance on electric buses can vary in different weather conditions. For example, an electric school bus might not go as far on a full charge at 15 degree weather as it would at 75 degree weather. In cold weather, battery performance tends to decrease, reducing the vehicle's range due to factors like increased battery resistance and energy demand for heating systems. Conversely, in hot weather, high temperatures can also impact battery efficiency and decrease range. Additionally, factors such as wind, precipitation, and road conditions can further affect range. To make the most out of your batt, you'll want to plan your routes with consideration of when and where to charge, how far your bus can travel on a single charge in optimal conditions, and the health of your bus's battery.

### How does an electric shock happen?

Electric shock happens when a person's body becomes part of an electrical circuit, allowing current to flow through the body. When you touch an electrical source that has voltage (electrical pressure), such as a live wire or an exposed part of an electrical appliance, your body provides a path for the electricity to travel through. The electricity flows through your body, following the path of least resistance. This path includes parts of your body that come into contact with the electrical source.

### How can I be safe around electricity?

You should follow safety instructions provided by the bus manufacturer, your employer or union. You should educate yourself about electric vehicle safety to understand the risks associated with high-voltage systems and take appropriate precautions when around electric buses. By staying informed and following safety guidelines, you can ensure your safety when interacting with electric buses and charging infrastructure.

The Workforce Development Institute (WDI) is a statewide non-profit that works to increase opportunities for all New Yorkers to succeed in the workforce while earning family-sustaining wages. Learn more at [wdiny.org](http://wdiny.org).