INTRODUCTION TO ELECTRICITY & OHM'S LAW

MSLETB - ELECTRICAL INSTRUMENTATION PHASE 2

MODULE 1: FOUNDATIONAL CONCEPTS

SESSION 1.1: INTRODUCTION & ATOMIC THEORY

WHY ARE WE HERE?

The Importance of Electricity

- **Question:** What is the one thing almost every trade on a modern job site depends on?
    - **Answer:** Electricity.
- From power tools for carpenters to control systems for plumbers and HVAC technicians, a solid understanding of electricity is **essential for safety and success** in any skilled trade.
- **Course Goal:** To build your knowledge from the ground up, starting with the very basics, so you can work **safely and competently**.

THE BUILDING BLOCK OF EVERYTHING: THE ATOM

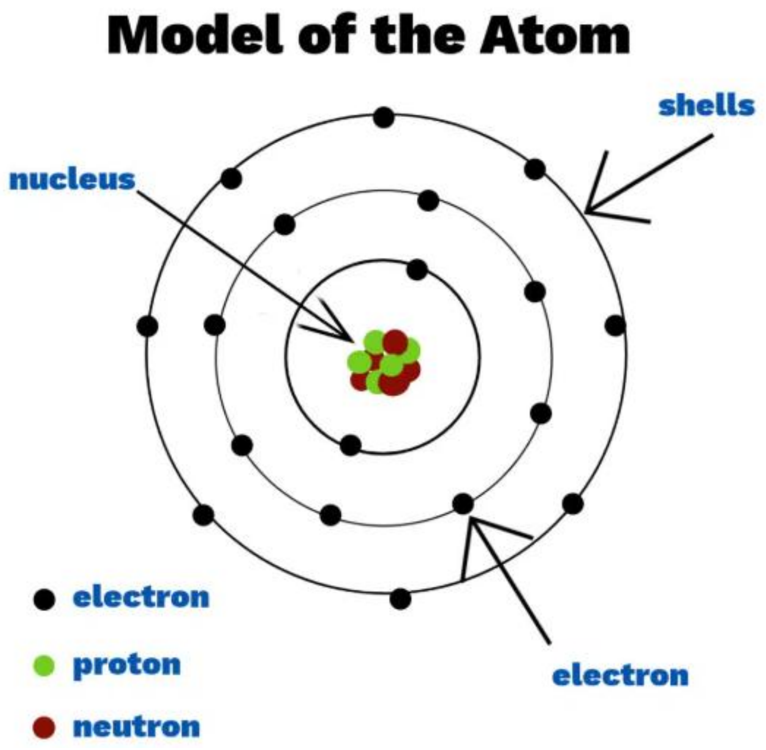
- Everything in the universe—from the copper in a wire to the air we breathe—is made up of **atoms**.
- An atom is the smallest particle of an element that still has the properties of that element.
- To understand electricity, we must first understand the structure of the atom.

INSIDE THE ATOM

An atom has two main parts: the **Nucleus** and the orbiting **Electrons**.

- **The Nucleus (The Center)**
  - **Protons:** Have a **POSITIVE** (+) electrical charge.
  - **Neutrons:** Have **NO** charge (they are neutral).
- **The Orbiting Particles**
  - **Electrons:** Have a **NEGATIVE** (-) electrical charge. They are very small and orbit the nucleus at high speed.

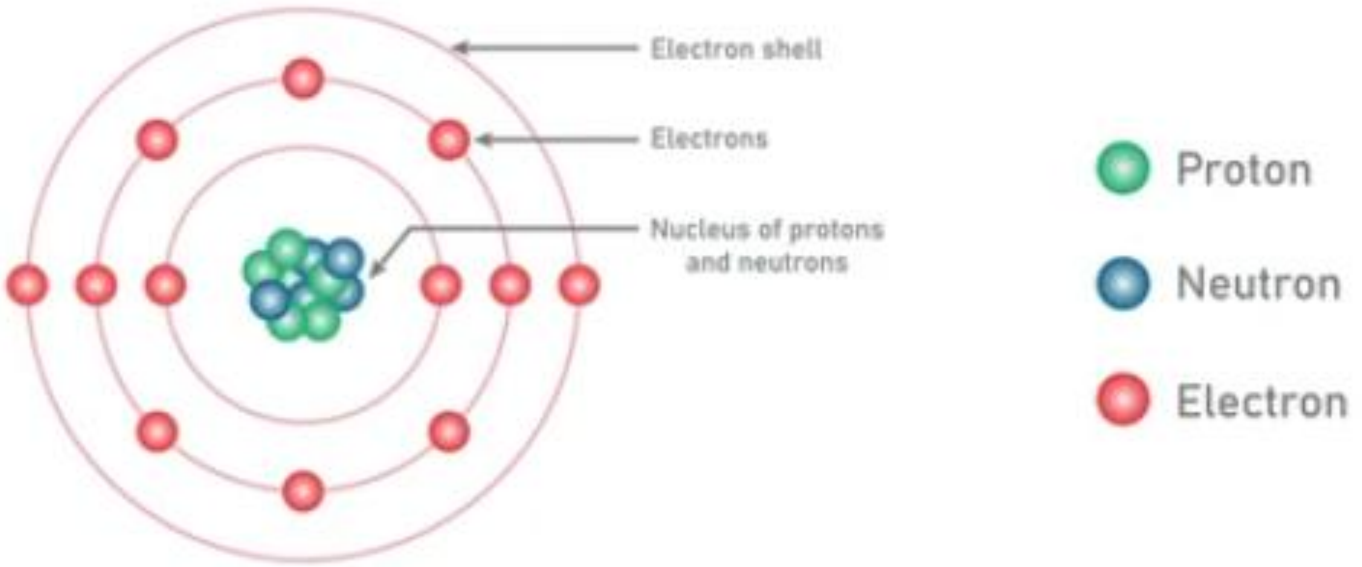
Key Point: In a normal atom, the number of electrons (-) is **equal** to the number of protons (+). This makes the atom electrically neutral.



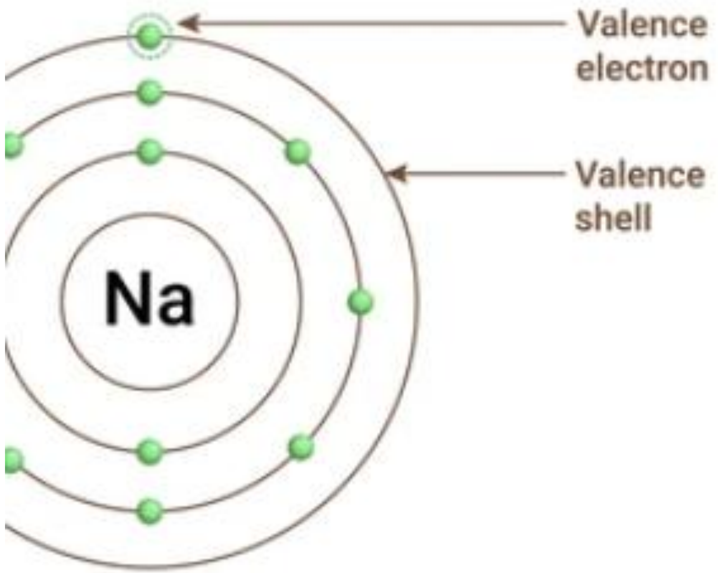
THE MOST IMPORTANT PART: ELECTRON SHELLS

- Electrons don't just orbit randomly; they stay in specific paths called **shells** or **energy levels**.
- Think of it like planets orbiting the sun in our solar system.
- Each shell can only hold a certain number of electrons.

The shell furthest from the nucleus is the most important one for electricity.



THE VALENCE SHELL - THE KEY TO ELECTRICITY



- The outermost shell of an atom is called the **VALENCE SHELL**.
- The electrons in this shell are called **valence electrons**.
- **The flow of electricity is the flow of electrons.**
- How easily an electron can leave its valence shell determines if a material will be a good conductor of electricity or not.

  If a valence electron can be easily "knocked out" of its shell, it can move freely and contribute to electric current.

ACTIVITY TIME

Goal: To see the difference between an atom of a **conductor** and an atom of an **insulator**.

You will need:

- Pen / Pencil
- Paper

We will draw two different atoms:

- **Copper:** A great electrical conductor.
- **Neon:** A gas used in signs, which is an electrical insulator.

ACTIVITY: DRAW A CONDUCTOR (COPPER)

Copper Atom (Cu)

- **Protons:** 29 (+)
- **Electrons:** 29 (-)

Shell Structure:

- 1st Shell: 2 electrons
- 2nd Shell: 8 electrons
- 3rd Shell: 18 electrons
- **Valence Shell (4th): 1 electron**

  Draw this atom. Notice how lonely that one valence electron is. It's not held tightly and can easily be pushed out!

ACTIVITY: DRAW A CONDUCTOR (COPPER)

Copper Atom (Cu)

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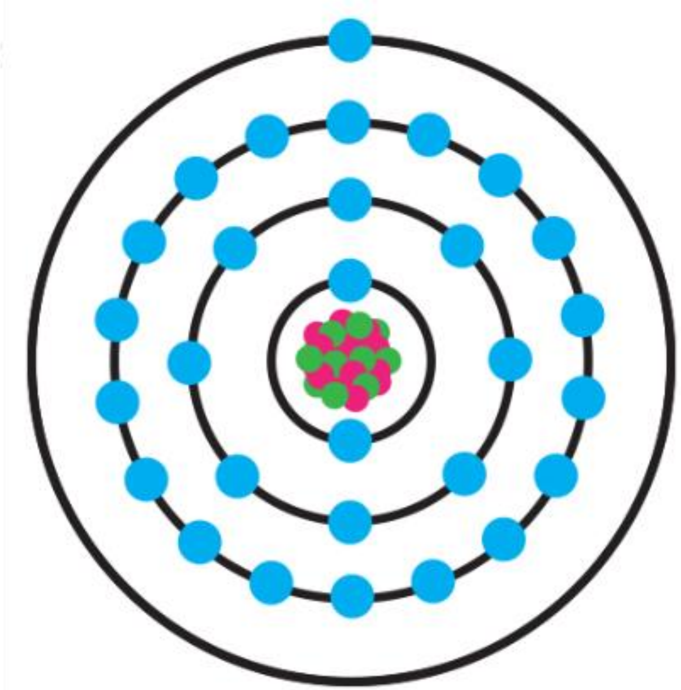

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- **Valence Shell (4th): 1 electron**

  Draw this atom. Notice how lonely that one valence electron is. It's not held tightly and can easily be pushed out!

ACTIVITY: DRAW AN INSULATOR (NEON)

Neon Atom (Ne)

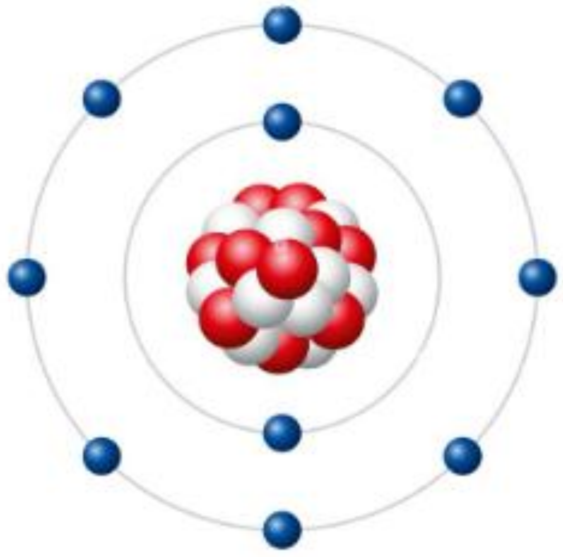
- **Protons:** 10 (+)
- **Electrons:** 10 (-)

Shell Structure:

- 1st Shell: 2 electrons
- **Valence Shell (2nd): 8 electrons**

Draw this atom. The valence shell is full and stable (8 is a happy number for shells). These electrons are held very tightly and are not free to move.

ACTIVITY: DRAW AN INSULATOR (NEON)



Neon Atom (Ne)

- **Protons:** 10 (+)
- **Electrons:** 10 (-)

  Shell Structure:

- 1st Shell: 2 electrons
- **Valence Shell (2nd): 8 electrons**

  Draw this atom. The valence shell is full and stable (8 is a happy number for shells). These electrons are held very tightly and are not free to move.

ACTIVITY DEBRIEF

What did we see?

- **Copper (Conductor):**
  - Has only **1 valence electron**.
  - This electron is far from the nucleus and weakly held.
  - It requires very little energy to make it leave the atom and become a "free electron."
- **Neon (Insulator):**
  - Has **8 valence electrons**.
  - The valence shell is full and stable.
  - It requires a huge amount of energy to remove an electron.

Conclusion: The number of valence electrons is the key difference between conductors and insulators.

MODULE 1: FOUNDATIONAL CONCEPTS

SESSION 1.2: CHARGE, FORCE, AND MATERIALS

WHAT IS ELECTRIC CHARGE?

- **Charge** is a fundamental physical property of matter that causes it to experience a force when placed in an electromagnetic field.
- It's the property that we assigned to Protons (+) and Electrons (-).
- We measure electric charge in a unit called the **COULOMB (C)**.

Analogy:

- Just like we measure distance in 'metres' or mass in 'kilograms'...
- We measure charge in 'Coulombs'.

A single Coulomb is a huge amount of charge: **1 Coulomb = the charge of approx. 6.24 quintillion electrons!** (6.24×10^{18})

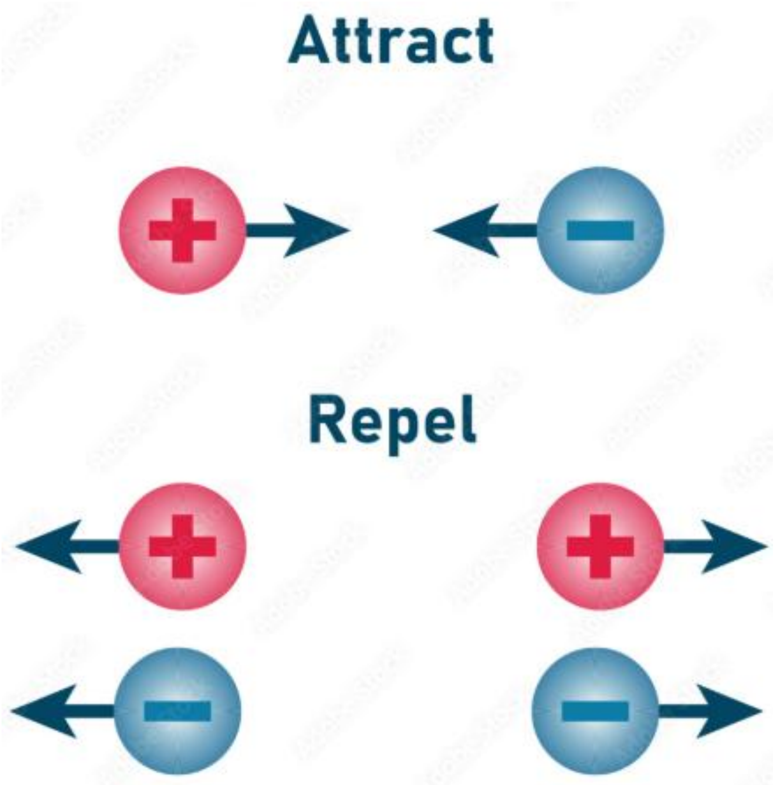
Think of it like this: instead of counting individual grains of sand, we count bags of sand. The Coulomb is like a "bag" that contains a massive number of electron charges (approximately 6.24×10^{18} electrons!). When we talk about an electric current of 1 Ampere (A), it means that 1 Coulomb of charge (one "bag" of electrons) is flowing past a point in a wire every single second.

THE LAW OF CHARGES: COULOMB'S LAW

The fundamental rule of how charges interact is simple and universal:

- **Opposite Charges ATTRACT**
  - A positive charge and a negative charge will pull toward each other.
- **Like Charges REPEL**
  - Two positive charges will push away from each other.
  - Two negative charges will also push away from each other.

This law of attraction and repulsion is the force that makes electrons move.



MATERIALS & ELECTRON FLOW

Based on what we've learned about valence electrons and Coulomb's Law, we can now classify materials based on how easily they allow electrons to move.

There are three main categories:

- **Conductors**
- **Insulators**
- **Semiconductors**

CONDUCTORS

- **Definition:** Materials that allow electric charge (electrons) to flow through them easily.
- **Atomic Structure:** They have **1 to 3 valence electrons** that are loosely held by the nucleus.
- These "free electrons" can be easily pushed from one atom to the next.

Examples:

- **Best:** Silver, Copper, Gold, Aluminum
- **Good:** Brass, Steel, most other metals.

Copper is the most common conductor used in electrical wiring because it offers a great balance of conductivity and cost.

INSULATORS

- **Definition:** Materials that **resist** or prevent the flow of electric charge.
- **Atomic Structure:** They have **5 to 8 valence electrons**. Their valence shell is full or nearly full.
- Electrons are held very tightly to the nucleus and are not free to move.

Examples:

- Rubber
- Plastic
- Glass
- Porcelain
- Dry Wood
- Air

Insulators are essential for safety, used to cover wires and protect us from electric shock.

SEMICONDUCTORS

- **Definition:** Materials that are neither good conductors nor good insulators.
- **Atomic Structure:** They have exactly **4 valence electrons**.
- Their properties can be precisely controlled by adding impurities (a process called "doping").

Examples:

- Silicon (Si)
- Germanium (Ge)

Semiconductors are the foundation of all modern electronics: diodes, transistors, computer chips, solar panels, etc.

SUMMARY TABLE

Property	**Conductors**	**Insulators**	**Semiconductors**
Valence Electrons	1-3 (Few)	5-8 (Many)	4 (Exactly)
Electron Mobility	Very High (Free)	Very Low (Bound)	Can be controlled
Resistance to Flow	Very Low	Very High	Moderate
Purpose	To allow current flow	To block current flow	To control current flow
Example	Copper Wire	Rubber Sheath	Computer Chip

MODULE 1 RECAP

- All matter is made of **atoms**.
- Atoms contain **protons (+), neutrons, and electrons (-)**.
- The **valence shell** is the key to electrical properties.
- **Conductors** have few valence electrons and let current flow easily.
- **Insulators** have many valence electrons and block current flow.
- **Semiconductors** have 4 valence electrons and are used to control flow.
- The law of charges states that **opposites attract** and **likes repel**.

MODULE 2: ELECTRICAL QUANTITIES

SESSION 2.1: EMF AND ELECTRIC CURRENT

THE "BIG THREE" OF ELECTRICITY

To understand any electrical circuit, you must know these three key quantities:

- **Voltage (V):** The electrical pressure or "push."
- **Current (I):** The rate of electrical flow.
- **Resistance (R):** The opposition to flow.

We will use a simple water pipe analogy to understand how they relate to each other.

ELECTROMOTIVE FORCE (EMF) / VOLTAGE

- **Definition:** Electromotive Force (EMF), more commonly called **Voltage**, is the potential difference or pressure that causes electrons to move in a circuit.
- It's the "push" that forces electrons away from a negative point and towards a positive one.
- **Unit of Measurement:** The **Volt (V)**.

Without voltage, there is no push, and therefore no current can flow.

WATER ANALOGY: VOLTAGE IS PRESSURE

- **High Voltage** is like a full water tower. It creates a lot of pressure, with the potential to push a large amount of water.
- **Low Voltage** is like a nearly empty water tower. There is very little pressure, so it can only push a small amount of water.

WHERE DOES VOLTAGE COME FROM? SOURCES OF EMF

Voltage is created by converting other forms of energy into electrical energy.

1. Chemical Source: Cells & Batteries

- **How it works:** A chemical reaction inside the cell creates a buildup of electrons at the negative terminal (-) and a shortage at the positive terminal (+), resulting in a voltage.
- **Primary Cells:** Non-rechargeable (e.g., standard AA, AAA batteries).
- **Secondary Cells:** Rechargeable (e.g., car batteries, phone batteries).

SOURCES OF EMF (CONTINUED)

2. Magnetic Source: Generators

- **How it works:** Based on the principle of **electromagnetic induction**. When a wire is moved through a magnetic field, a voltage is "induced" in the wire. This is how almost all the world's electricity is generated.

  3. Other Sources

- **Thermal (Thermocouples):** Heating a junction of two different metals creates a small voltage. Used for temperature sensors.
- **Light (Photovoltaic Cells):** Light striking a semiconductor material (like silicon) knocks electrons free, creating a voltage. This is how solar panels work.

ELECTRIC CURRENT

- **Definition:** Electric Current is the rate of flow of electric charge through a conductor. It's the measure of how many electrons are moving past a point in a certain amount of time.
- **Unit of Measurement:** The **Ampere (A)**, often just called "Amps".
- The symbol for current in formulas is **I** (from the French *intensité du courant*).

  Current is what does the work in a circuit (e.g., lights a lamp, turns a motor).

WATER ANALOGY: CURRENT IS FLOW RATE

- **High Current** is like a wide pipe with lots of water flowing through it (many litres per second).
- **Low Current** is like a narrow pipe with only a trickle of water flowing through it (few litres per second).

THE RELATIONSHIP BETWEEN CURRENT AND CHARGE

Remember that charge (Q) is measured in Coulombs, and Current (I) is measured in Amps.

1 Ampere is defined as 1 Coulomb of charge flowing past a point in 1 second.

This gives us a very useful formula: **Q = I x t**

- **Q** = Quantity of Charge (in Coulombs)
- **I** = Current (in Amps)
- **t** = time (in **seconds**)

CALCULATION PRACTICE

Question 1: A current of 5 Amps flows through a lamp for 2 minutes. What quantity of electricity (charge) is transferred?

- **Step 1:** Convert time to seconds. 2 minutes x 60 = 120 seconds.
- **Step 2:** Use the formula Q = I x t.
- **Step 3:** Q = 5 A x 120 s
- **Answer:** Q = 600 C

Question 2: If 540 Coulombs of charge passes through a point in 2 minutes, what is the current?

- **Step 1:** Rearrange the formula: I = Q / t
- **Step 2:** Time in seconds = 2 x 60 = 120 s
- **Step 3:** I = 540 C / 120 s
- **Answer:** I = 4.5 A

MODULE 2: ELECTRICAL QUANTITIES

SESSION 2.2: RESISTANCE & CURRENT FLOW

CONVENTIONAL VS. ELECTRON FLOW

The Big Question: Which way does electricity *actually* flow?

This is one of the most confusing topics for new apprentices, but it's simple once you understand the history. There are two "correct" answers:

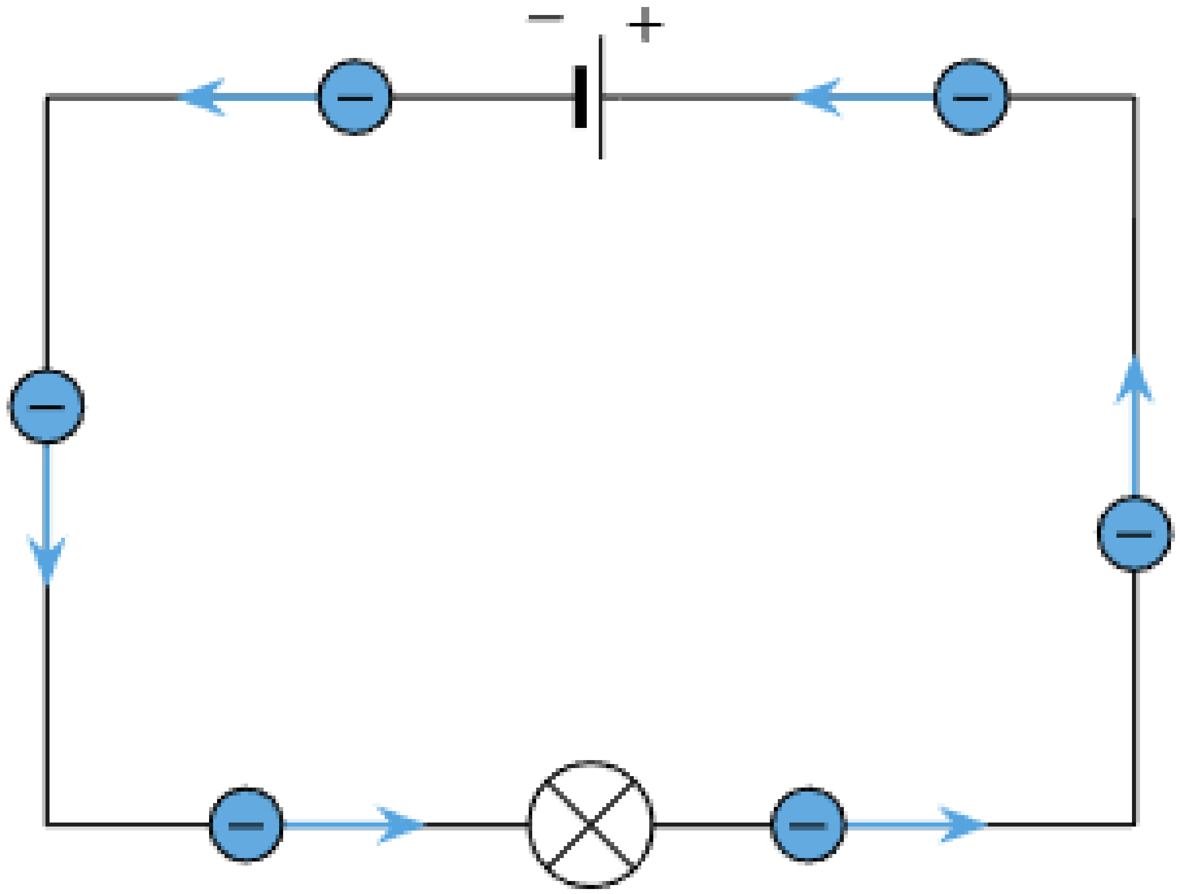
- **Electron Flow:** What is physically happening.
- **Conventional Flow:** The standard used on all drawings and for all calculations.

You MUST understand both.

ELECTRON FLOW THEORY (THE PHYSICAL REALITY)

- We know that electrons are **negatively** charged particles.
- The negative terminal of a battery has a surplus of electrons.
- The positive terminal has a shortage of electrons.
- Based on the Law of Charges (opposites attract, likes repel), electrons are repelled from the negative terminal and attracted to the positive terminal.

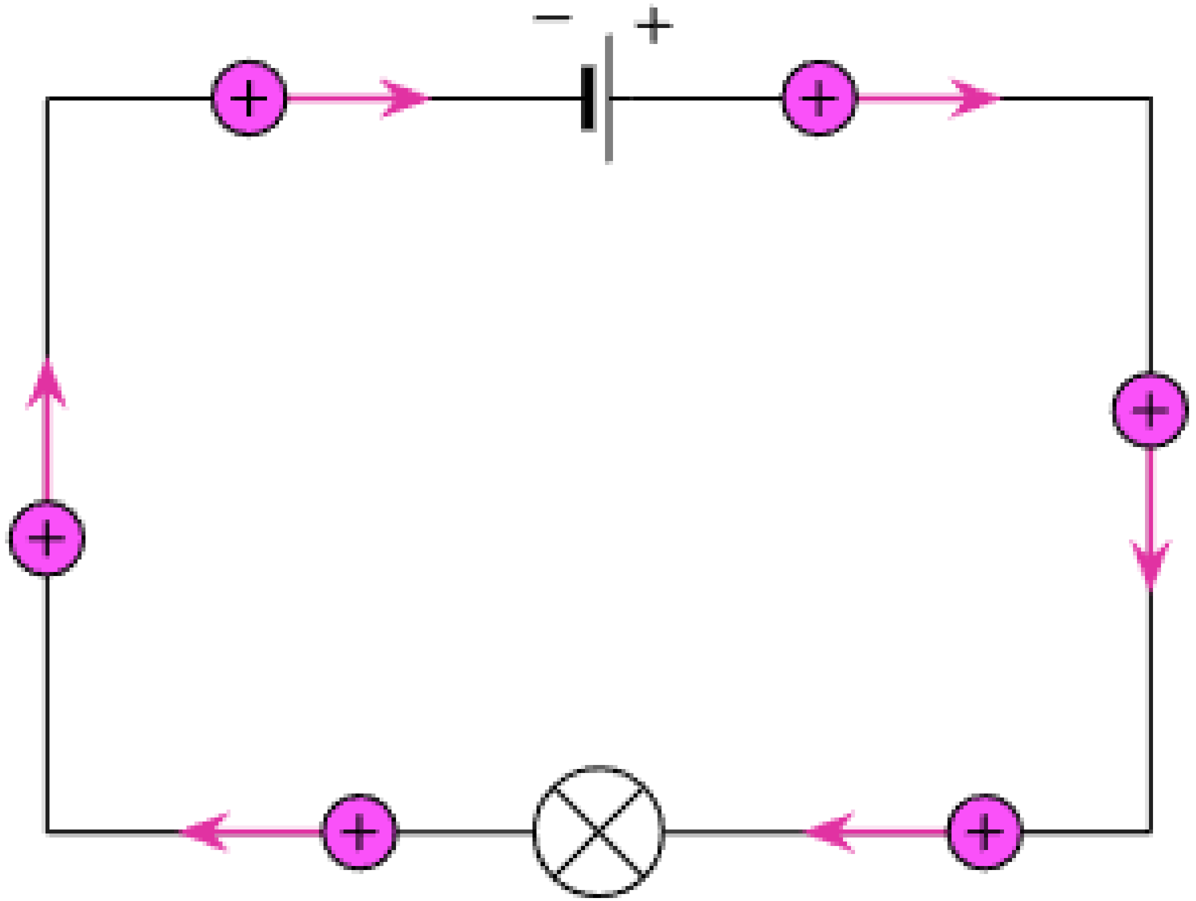
Therefore, electrons physically flow from NEGATIVE (-) to POSITIVE (+).



CONVENTIONAL CURRENT THEORY (THE INDUSTRY STANDARD)

- Early scientists, like Benjamin Franklin, studied electricity before the electron was discovered.
- They *assumed* that electricity was the flow of some kind of positive fluid.
- Therefore, they established the convention that current flows from a point of high potential (+) to a point of low potential (-).
- By the time the electron was discovered, this convention was already the standard for all diagrams and formulas worldwide. It was too late to change.

Therefore, for all electrical work, we assume current flows from POSITIVE (+) to NEGATIVE (-).



SEEING BOTH FLOWS

Rule of Thumb:

- When you are thinking about physics and what is *actually* happening, think **Electron Flow**.
- When you are looking at a schematic, drawing a circuit, or doing calculations, you **MUST** use **Conventional Flow**.

RESISTANCE

- **Definition:** Resistance is the opposition to the flow of electric current.
- It's a measure of how difficult it is for electrons to pass through a material.
- Resistance converts electrical energy into heat energy.
- **Unit of Measurement:** The **Ohm**.
- **Symbol:** The Greek letter Omega (**Ω**).

WATER ANALOGY: RESISTANCE IS OBSTRUCTION

- **Low Resistance** is like a wide, clear pipe. Water flows through it easily.
- **High Resistance** is like a narrow, rusty, or blocked pipe. It's very difficult to push water through it.

FOUR FACTORS AFFECTING RESISTANCE

The resistance of a conductor depends on four key factors:

- **Length**
- **Cross-Sectional Area (Thickness)**
- **Material Type (Resistivity)**
- **Temperature**

Let's look at each one.

FACTOR 1: LENGTH

The longer a conductor, the higher its resistance.

- **Analogy:** It's harder to push water through a very long hose than a short one because of the increased friction.
- **Reason:** A longer wire means the electrons have to travel past more atoms, and each collision with an atom causes opposition.

  Resistance is directly proportional to length. (If you double the length, you double the resistance).

FACTOR 2: CROSS-SECTIONAL AREA (C.S.A)

The thicker a conductor, the lower its resistance.

- **Analogy:** A wide fire hose has less resistance to water flow than a narrow garden hose.
- **Reason:** A thicker wire provides more available paths for the electrons to flow through.

Resistance is inversely proportional to cross-sectional area. (If you double the area, you halve the resistance).

FACTOR 3: MATERIAL TYPE (RESISTIVITY)

Every material has its own natural, built-in opposition to current flow. This property is called resistivity.

- As we learned in Module 1, conductors have very low resistivity.
- Insulators have very high resistivity.

Example Resistivity (at 20°C):

- **Copper:** 1.68×10^{-8} $\Omega \cdot m$ (very low)
- **Glass:** 10^{10} to 10^{14} $\Omega \cdot m$ (extremely high)

FACTOR 4: TEMPERATURE

For most conductors, as temperature increases, resistance increases.

- **Reason:** Heating a material causes its atoms to vibrate more rapidly. This makes it more difficult for electrons to find a clear path through, leading to more collisions and higher resistance.
- **Note:** This is not true for all materials. Semiconductors, for example, typically decrease their resistance as they get hotter.

MODULE 2 RECAP

- **Voltage (V)** is the pressure that pushes current. Measured in **Volts**.
- **Current (I)** is the rate of flow. Measured in **Amps**.
- **Resistance (R)** is the opposition to flow. Measured in **Ohms (Ω)**.
- **Conventional Flow (+ to -)** is the standard used for all circuit analysis.
- Resistance is affected by a conductor's **length, thickness, material type, and temperature**.

MODULE 3: OHM'S LAW & CIRCUIT ANALYSIS

SESSION 3.1: THE SIMPLE CIRCUIT & OHM'S LAW

THE ELECTRIC CIRCUIT

For electricity to do useful work, we need a complete **circuit**. A circuit is simply a closed loop or path that allows current to flow.

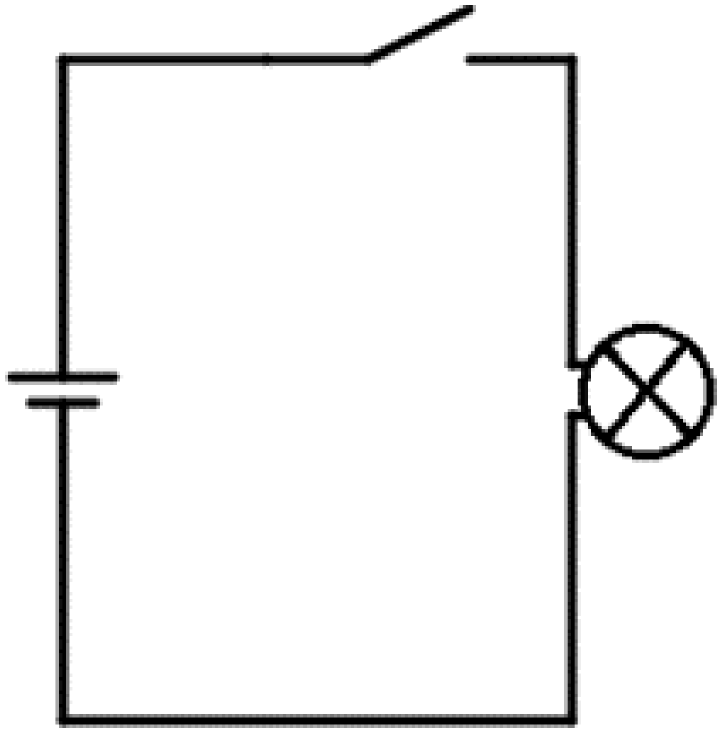
Every useful circuit has four essential parts:

- **Source:** Provides the voltage (EMF). (e.g., a battery)
- **Path:** The conductors that carry the current. (e.g., copper wires)
- **Load:** The device that uses the electricity and provides resistance. (e.g., a lamp)
- **Control:** A device to open or close the circuit. (e.g., a switch)

A SIMPLE CIRCUIT DIAGRAM

Here are the four parts working together:

When the **Control** (switch) is closed, the loop is complete, and current flows from the **Source**, through the **Path**, to the **Load**, and back to the source.



OPEN CIRCUITS

- An **Open Circuit** is a circuit where the path has been broken.
- This could be due to an open switch, a broken wire, or a blown fuse.
- Because the loop is incomplete, **no current can flow**.
- An open circuit has **infinite resistance**.

SHORT CIRCUITS

- A **Short Circuit** is an unintended, low-resistance path for current to flow.
- It allows current to bypass the load.
- Because there is almost no resistance, Ohm's Law (I = V/R) tells us the current will become **dangerously high**.

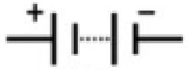
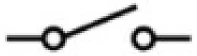
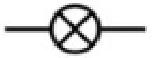
DANGER: Short circuits can cause wires to overheat, melt, and start fires. They are a major electrical hazard. Fuses and circuit breakers are designed to protect against this.

GRAPHICAL SYMBOLS

- Instead of drawing pictures of components, electricians use a standard set of **graphical symbols** to draw circuit diagrams (schematics).
- Learning these symbols is like learning the alphabet of electricity.

  We will now learn the most common symbols. You will be given a full chart for your reference.

COMMON COMPONENT SYMBOLS

Component	Symbol	Description
Cell	 Cell	A single source of DC voltage.
Battery	 Battery	Multiple cells connected together.
Resistor	 Resistor	A component that resists current flow.
Switch	 Switch (closed)  Switch (open)	Opens or closes a circuit.
Lamp	 Lamp	A load that produces light.
Fuse	 Fuse	A safety device that blows to open a circuit.

METER SYMBOLS & CONNECTION

Meters must be connected correctly to measure properly.

- **Ammeter (Measures Current)**
  - Symbol: --(A)--
  - Must be connected **IN SERIES** with the load (so all the current flows through it).
- **Voltmeter (Measures Voltage)**
  - Symbol: --(V)--
  - Must be connected **IN PARALLEL** with the load (across the component).
- **Ohmmeter (Measures Resistance)**
  - Symbol: --(Ω)--
  - Must only be used when the circuit is **DE-ENERGIZED** (power off).

HOW ELECTRICITY WORKS - WORKING PRINCIPLE

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MODULE 3: OHM'S LAW & CIRCUIT ANALYSIS

SESSION 3.2: OHM'S LAW CALCULATIONS & PREFIXES

OHM'S LAW

- **Definition:** Ohm's Law describes the relationship between voltage, current, and resistance. It states:

  "The current flowing through a conductor is directly proportional to the voltage across it and inversely proportional to the resistance, provided all physical conditions and temperature remain constant."

- In simple terms:
- If you increase the **voltage** (push), the **current** (flow) will increase.
- If you increase the **resistance** (opposition), the **current** (flow) will decrease.

THE OHM'S LAW FORMULA

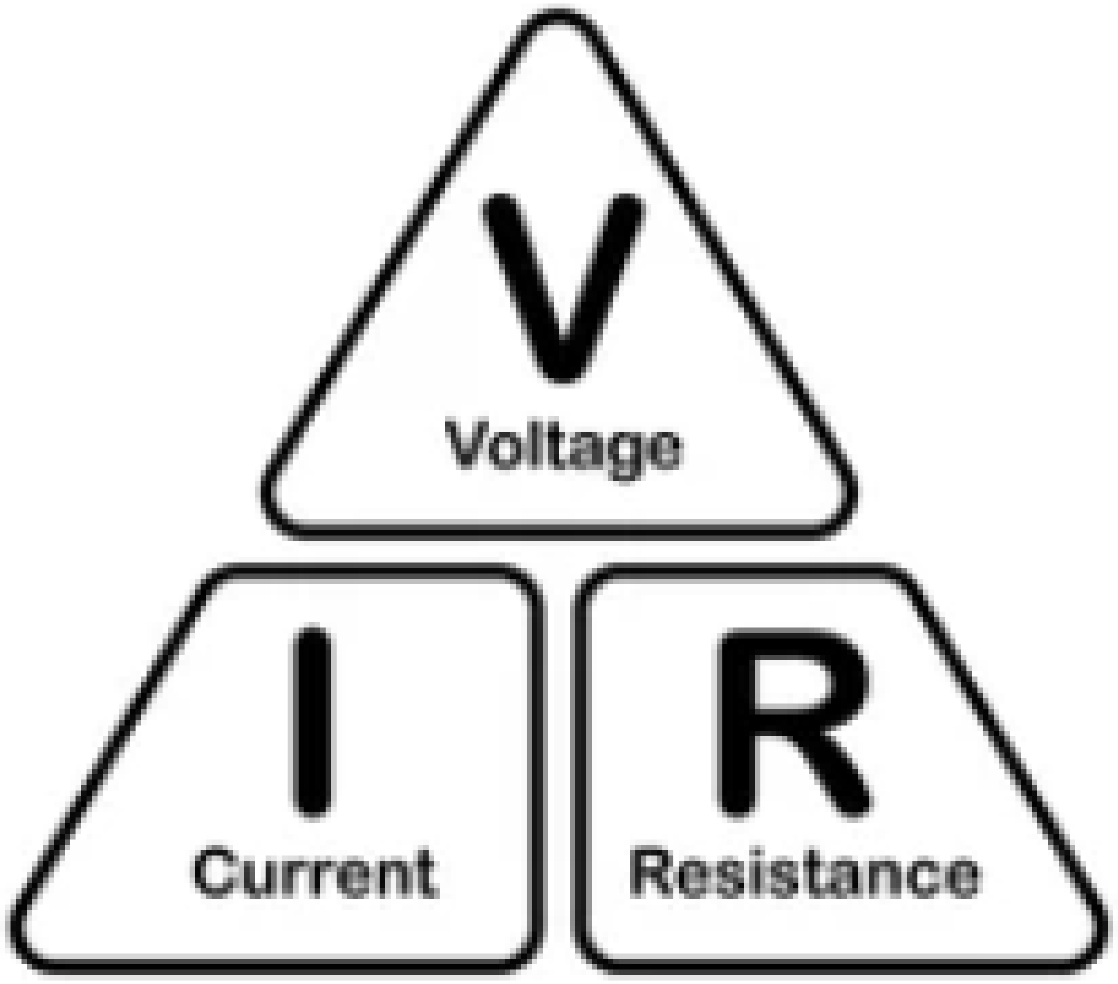
The relationship is expressed by the formula:

V = I x R

- **V** = Voltage (in Volts)
- **I** = Current (in Amps)
- **R** = Resistance (in Ohms)

  You can use the **Ohm's Law Triangle** to easily rearrange the formula to solve for any of the three variables.

- To find **V**: Cover V, which leaves I x R.
- To find **I**: Cover I, which leaves V / R.
- To find **R**: Cover R, which leaves V / I.



CALCULATION PRACTICE

Let's use the formula.

Example 1: A simple circuit has a 230Ω resistor connected to a power source. If a current of 5 Amps is flowing, what is the source voltage?

- **Known:** R = 230Ω, I = 5A
- **Unknown:** V
- **Formula:** V = I x R
- **Calculation:** V = 5A x 230Ω
- **Answer:** V = 1150 Volts

WORKING WITH LARGE & SMALL NUMBERS

In electrical / electronics, we often work with very large or very small numbers. We use **engineering prefixes** to make them easier to write.

Prefix	Symbol	Multiplier	Power of 10
Mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}
(none)		1	10^{0}
milli	m	0.001	10^{-3}
micro	µ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}

IMPORTANT: You must convert all values to their base units (Volts, Amps, Ohms) before doing calculations!

CALCULATION WITH PREFIXES

Example 2: A circuit has a resistance of 2 kΩ and a current of 50 mA is flowing. What is the voltage?

- **Step 1: Convert to base units.**
  - R = 2 kΩ = 2 x 1000 = **2000 Ω**
  - I = 50 mA = 50 / 1000 = **0.05 A**
- **Step 2: Use the formula.**
  - V = I x R
  - V = 0.05 A x 2000 Ω
- **Answer:** V = 100 Volts

OHMS LAW EXPLAINED - THE BASICS CIRCUIT THEORY

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WORKSHEET ACTIVITY

Now it's your turn to practice.

Please take a worksheet and complete the Ohm's Law problems.

- Remember to show your work.
- Write down the formula you are using.
- Convert all prefixes to base units before calculating.
- Don't forget the units in your final answer!

MODULE 3 RECAP

- A circuit needs a **Source, Path, Load, and Control** to work.
- **Open circuits** have no current flow, while **short circuits** have dangerously high current flow.
- **Graphical symbols** are the language of electrical diagrams.
- **Ohm's Law (V = I x R)** is the fundamental formula that connects voltage, current, and resistance.
- Always convert **prefixes** to base units (Volts, Amps, Ohms) before calculating.

MODULE 4: PRACTICAL APPLICATION, SAFETY & ASSESSMENT

SESSION 4.1: PRACTICAL LAB & EFFECTS OF CURRENT

LAB PREP & MULTIMETER USE

Safety First!

- This is a low-voltage lab, but good safety habits start now.
- Always handle equipment carefully.
- Wear safety glasses.
- Keep your workspace tidy.
- If you are unsure about something, **ASK!**

The Digital Multimeter (DMM)

- This is your most important tool for electrical measurements.
- We will use it to measure Voltage (V), Current (A), and Resistance (Ω).
- **Crucial Rule:** The way you connect the meter depends on what you are measuring.

CONNECTING YOUR METERS

Measuring Voltage (IN PARALLEL)

- The voltmeter is connected *across* the component to measure the pressure difference between two points.

  Measuring Current (IN SERIES)

- The ammeter must be connected *in line* with the components, so the current has to flow *through* the meter to be measured. You have to break the circuit to insert the ammeter.

  Measuring Resistance (POWER OFF)

- The ohmmeter provides its own small voltage. **NEVER** use it on a circuit with the power on. You must remove the component from the circuit to get an accurate reading.

PRACTICAL LAB: VERIFYING OHM'S LAW

To build a simple circuit and prove that our measured values for V, I, and R match the Ohm's Law formula ($V = I \times R$).

Procedure (per group):

- **Measure Resistance:** With the power OFF, use the DMM to measure the exact resistance of your resistor. Record this value.
- **Build the Circuit:** On your breadboard, build a simple circuit with the power supply and the resistor.
- **Set Voltage:** Turn the power supply on and set it to 5 Volts.
- **Measure Voltage:** Connect the voltmeter in parallel with the resistor and record the exact voltage.
- **Measure Current:** Turn the power OFF. Break the circuit and connect the ammeter in series. Turn the power back ON and record the current.
- **Calculate:** Use your measured V and I to calculate resistance ($R = V / I$).
- **Verify:** Compare your calculated resistance to the resistance you measured in Step 1. They should be very close!

EFFECTS OF CURRENT

As current flows through a circuit, it produces other effects. We can observe some of these in our lab.

- **Heating Effect**
  - As electrons flow through the resistor, their collisions with atoms generate heat.
  - *Observation:* Carefully touch your resistor. You may feel it get slightly warm. This effect is used in toasters, electric heaters, and fuses.
- **Magnetic Effect**
  - Every electric current generates a magnetic field around the conductor. This is the principle behind motors, generators, and transformers.
- **Chemical Effect**
  - Current can cause chemical reactions. This is the principle of batteries (charging/discharging) and electroplating.

MODULE 4: PRACTICAL APPLICATION, SAFETY & ASSESSMENT

SESSION 4.2: ELECTRICAL SAFETY

ELECTRICAL SAFETY: YOUR #1 PRIORITY

- This is the most important session of the entire course.
- Understanding the theory is great, but working safely ensures you have a long and successful career.
- Electricity is invisible and gives no warning. **Respect it, always.**

  "There are old electricians and there are bold electricians, but there are no old, bold electricians."

THE HUMAN BODY & ELECTRICITY

- Why is electricity dangerous? Because the human body is a conductor.
- Our nervous system works using tiny electrical signals. External current can override these signals with disastrous results.

Effects of Current (AC) on the Body:

- **1 mA:** Can just be felt (perception level).
- **5 mA:** Shock is painful.
- **10-20 mA:** Muscle contractions begin. Victim may not be able to let go ("let-go" threshold).
- **50-100 mA: Ventricular Fibrillation.** The heart's rhythm is disrupted. This is often fatal.
- **> 200 mA:** Severe burns and cardiac arrest.

It takes very little current to kill.

MAIN ELECTRICAL HAZARDS

- **Electric Shock:** Current passing through the body. The path the current takes is critical (e.g., hand-to-hand across the heart is most dangerous).
- **Burns:** Caused by current flowing through and heating body tissue, or by contact with overheated electrical components.
- **Arc Flash / Arc Blast:** An explosive release of energy from a high-amperage short circuit (e.g., dropping a metal tool in a live panel). Can cause fatal burns, pressure waves, and flying shrapnel.
- **Fire:** Caused by overloaded circuits, faulty wiring, or short circuits igniting flammable materials.

BASIC SAFETY RULES

- **ALWAYS** assume a circuit is live until you have proven it is dead.
- Use a known, working voltage tester to test for the absence of voltage.
- **Lockout/Tagout (LOTO):** De-energize and lock the power source before working on equipment. This is a life-saving procedure.
- Use insulated tools and wear appropriate Personal Protective Equipment (PPE).
- Never work on live equipment unless absolutely necessary and properly trained.
- Keep your work area clean and dry.

KEY TAKEAWAYS:

- Respect all voltages.
- A tiny amount of current can be fatal.
- Test Before You Touch.
- Lockout/Tagout saves lives.

MODULE 4: PRACTICAL APPLICATION, SAFETY & ASSESSMENT

SESSION 4.3: FINAL REVIEW & ASSESSMENT

COMPREHENSIVE REVIEW

Let's recap the entire course:

- **Module 1:** We learned about the **atom**, valence electrons, and how they determine if a material is a **conductor** or **insulator**.
- **Module 2:** We defined **Voltage (V)**, **Current (I)**, and **Resistance (R)**, and learned the difference between **Conventional and Electron Flow**.
- **Module 3:** We defined the parts of a circuit, learned **graphical symbols**, and mastered the **Ohm's Law formula (V=IR)**, including calculations with prefixes.
- **Module 4:** We verified Ohm's Law in the **lab** and covered the critical principles of **electrical safety**.

SUMMATIVE ASSESSMENT

Now it's time to put your knowledge to the test.

- You will now be given the assessment sheets.
- Please read each question carefully.
- Show your calculations where required.
- This assessment covers all the key learning outcomes of the course.