

احجز مكانك واستعد للامتحان بثقة كاملة

$$F = \frac{Gm_1m_2}{r^2}$$

ملزمة الفيزياء الفصل الثاني

12 عام English لعام 2026

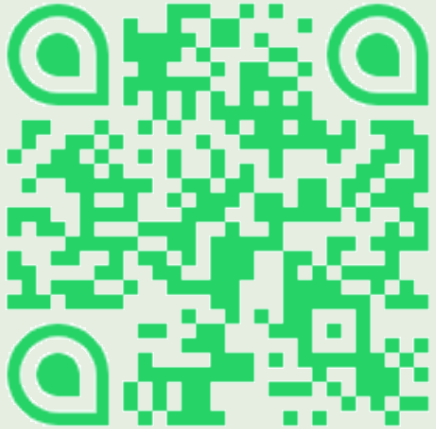
$$EF = ma$$

$$EF$$

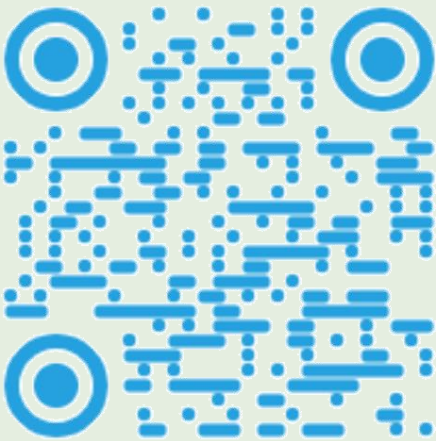
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تم إنشاء هذه الملزمة لمساعدتك، ولكن المرجع الرئيسي هو الكتاب،
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بـ 199
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احصل على شرح
الملزمة كاملة

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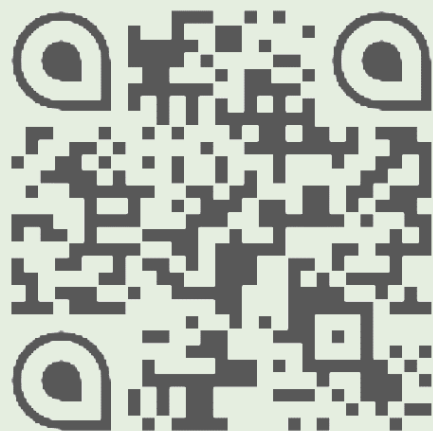
Unit (3): Electric Current

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Unit (3): Electric Current

01

First Section: Electric Current and Circuits



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The Journey of Energy

A Comprehensive Guide to Electric
Current and Circuits

Presented by Mr. Mohamad

What Powers Our Modern World?

From the computer on your desk to the phone in your hand, our lives are powered by countless tiny components working in perfect harmony. The secret to their operation is the controlled flow of electric charge.

“Electric current is the flow of electric charge.”

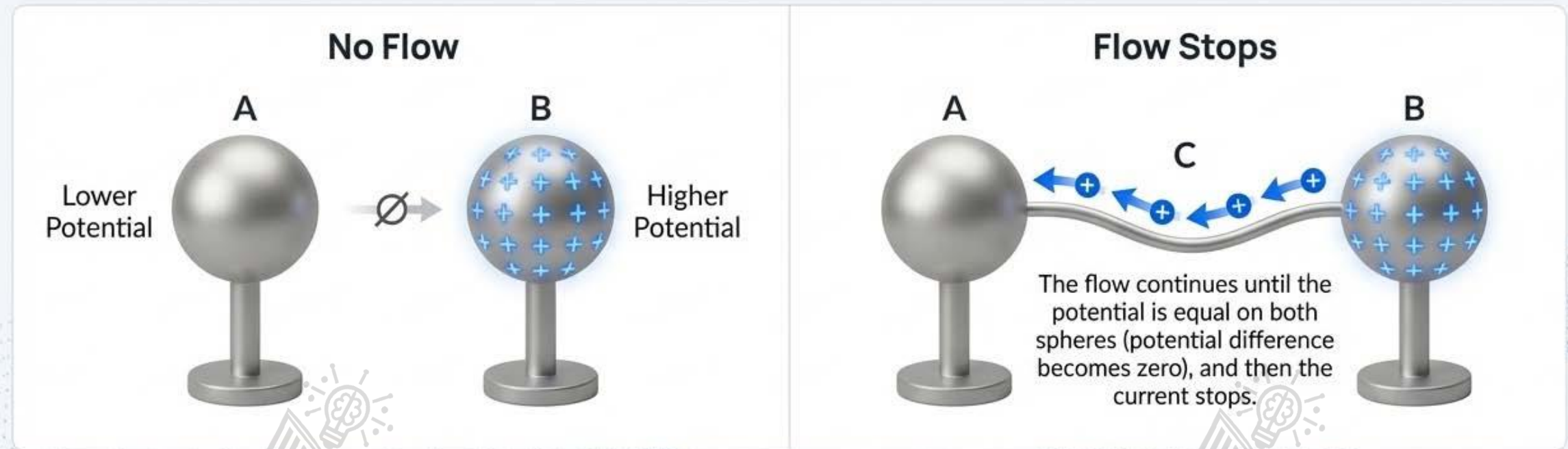
This lesson will answer:

- What is electric current?
- How does electrical energy change in circuits?
- What is the relationship between power, current, and voltage?



The Principle of Flow: From High to Low

Just as water flows downhill, **electric charge flows** from a point of **higher electric potential** to a point of lower potential. This flow of charged particles is the **electric current**.



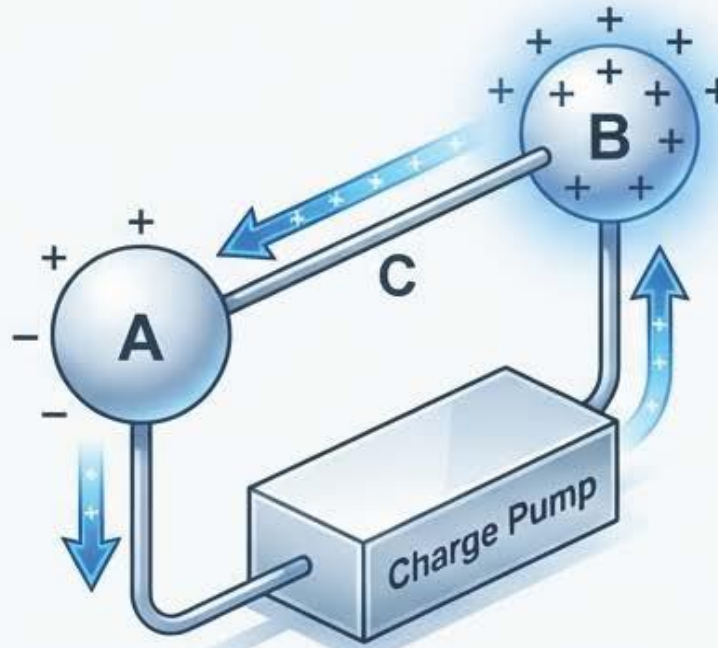
Key Definition: Conventional Current: The direction that positive charges would flow. (Note: In most conductors, it is actually the negative electrons that move in the opposite direction).

How to Keep the Current Flowing

To maintain a continuous flow, we need a “**charge pump**” to constantly re-establish the potential difference. This pump does work on the charges, increasing their potential energy.

The Problem

Without a pump, the current stops when potential is equalized.



The Solution

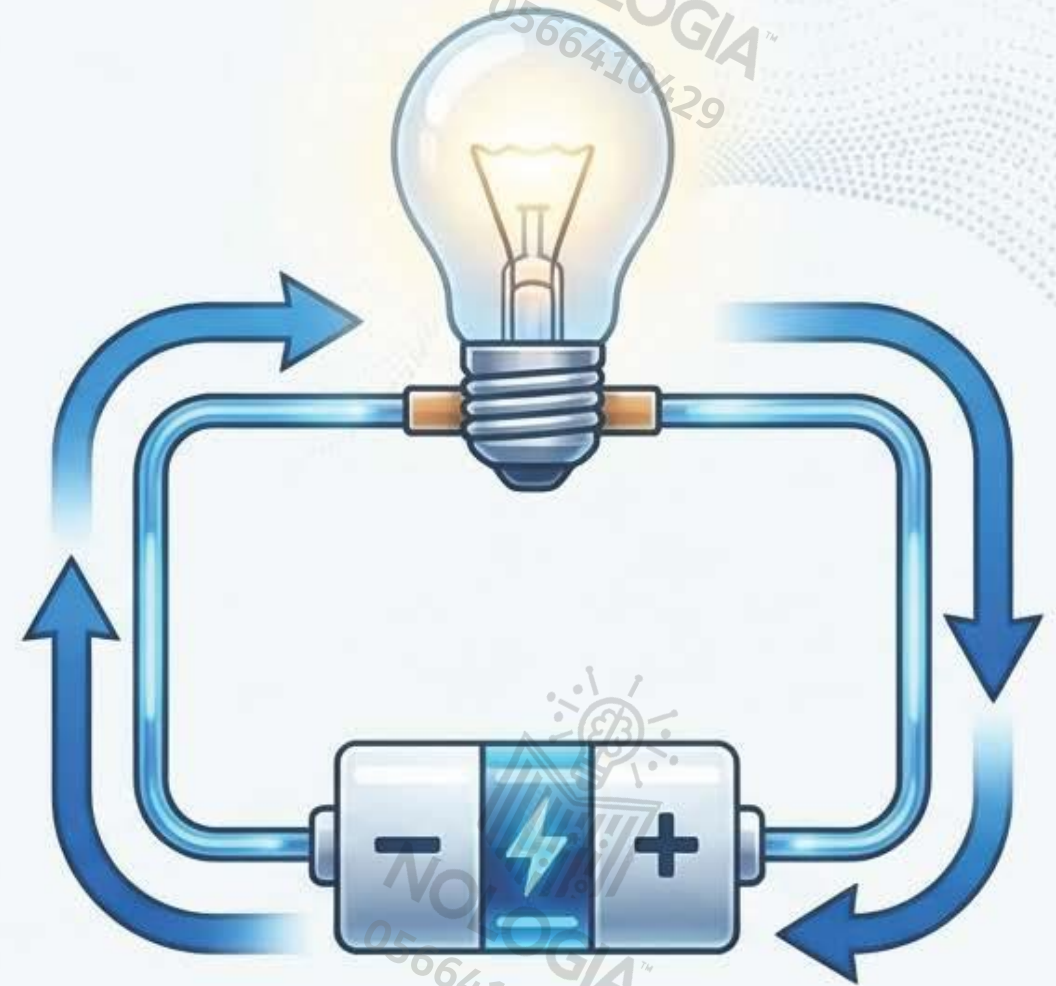
A **charge pump** maintains the potential difference, ensuring a continuous current.

Real-World Example: A **Voltaic Cell** (a basic battery) is a common charge pump that converts chemical energy into electrical energy. A series of cells forms a **battery**.

The System: The Electric Circuit

An **electric circuit** is any closed, continuous path that allows electric charges to flow. A simple circuit consists of two main parts:

1. **A source of potential energy:** The charge pump (e.g., a battery or generator) that *increases* the potential energy of the charges.
2. **A device or 'load':** An element like a motor or a lamp that *uses* the potential energy of the charges, converting it into another form (light, heat, motion).



The Master Analogy: How a Circuit is Like a Water Wheel

The height difference creates Gravitational Potential. This is like the **Voltage (Potential Difference)** provided by a battery.

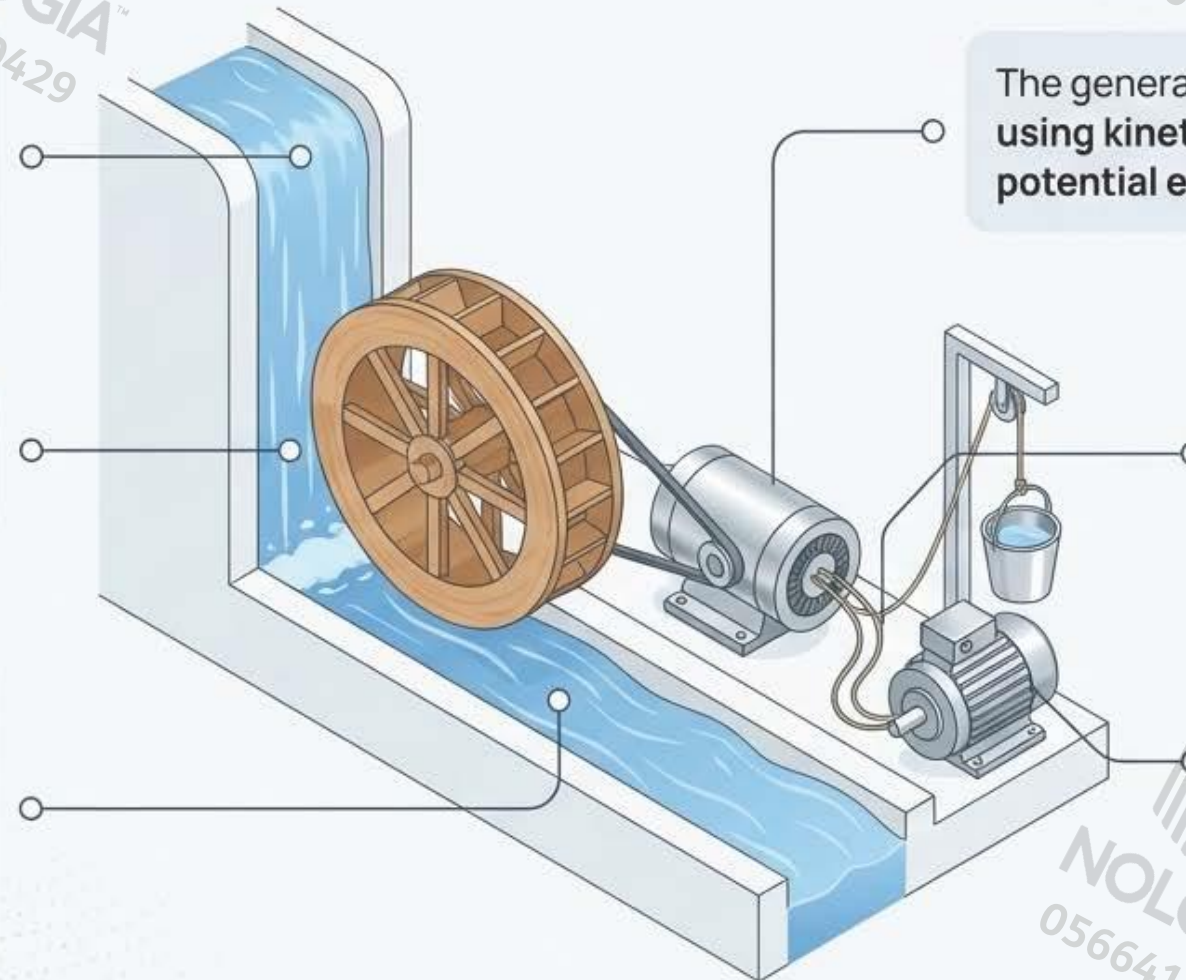
The rate of water flow is like the **Electric Current (Amps)**.

The generator acts as the **Charge Pump**, using kinetic energy to give electrical potential energy to the charges.

The generator acts as the **Charge Pump**, using kinetic energy to give electrical potential energy to for the charges.

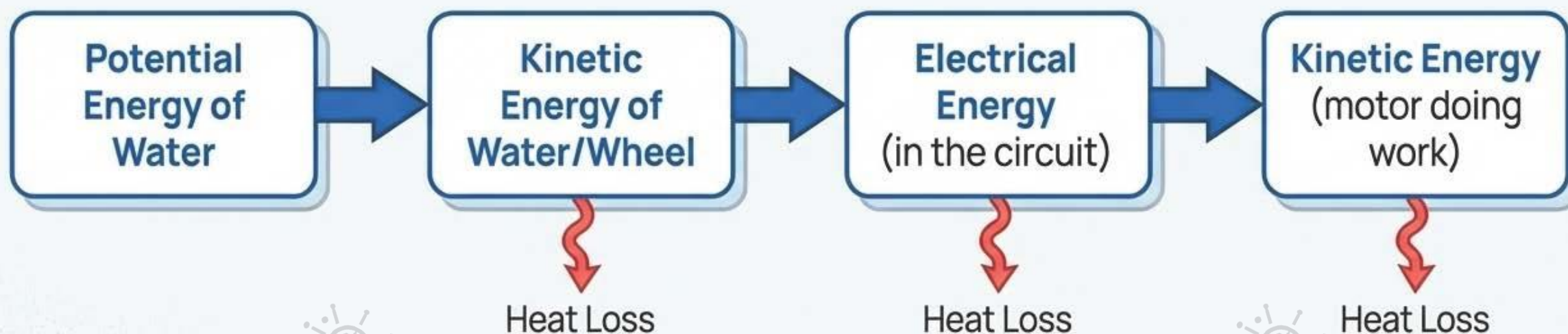
The connecting path for the charges.

The **Load** uses the electrical energy from the charges to do work.



The Journey of Energy: A Story of Transformation

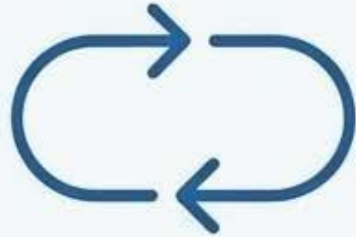
In a circuit, energy is not created or destroyed; it is converted from one form to another.



Key Point: Energy conversions are never 100% efficient. Some energy is always transformed into thermal energy due to factors like water splash, friction, and electrical resistance.

The Fundamental Rules of the Loop

Every circuit, no matter how complex, obeys two fundamental conservation laws.



Conservation of Charge

Charge is not “used up” in a circuit. The number of charges entering a component is the same as the number leaving it.

If 1 Coulomb of charge flows through the generator in 1 second, then 1 Coulomb also flows through the motor in that same second.



Conservation of Energy

The energy gained by a charge as it passes through the source is equal to the energy lost as it passes through the load(s).

The net change in potential energy for a charge making a complete trip around the circuit is zero.

Quantifying the Flow: Measuring Current

We measure the rate of charge flow as **electric current (I)**.

Formula Spotlight

$$I = \frac{q}{t}$$

I = Electric Current, measured in **Amperes (A)**

q = Electric Charge, measured in **Coulombs (C)**

t = Time, measured in **seconds (s)**

One Ampere is the flow of one Coulomb of charge per second (1 A = 1 C/s).

Quantifying the Work: Measuring Power

Power (P) is the rate at which energy is transferred or converted. It tells us how quickly a device uses electrical energy. The unit of power is the **Watt (W)**.

Definition: Power is the rate of energy transfer: $P = E / t$



This hairdryer is rated at **1875 W**. This means it converts 1875 Joules of electrical energy into thermal and kinetic energy every second.

The Power Equation: Linking Voltage and Current

The power consumed by an electrical device depends on both the current flowing through it and the potential difference (voltage) across it.

Simple Derivation

We know $P = E/t$ and $E = q\Delta V$. → Substituting for E , we get $P = (q\Delta V)/t$. → Since $I = q/t$, we arrive at the final equation.

Formula Spotlight

$$P = I\Delta V$$

P = Power, measured in **Watts (W)**

I = Current, measured in **Amperes (A)**

ΔV = Potential Difference, measured in **Volts (V)**

Worked Example: Power and Energy in a Motor

A 6.0 V battery supplies a 0.50 A current to an electric motor. The motor runs for 5.0 minutes.
a. What is the power delivered to the motor? **b.** How much electrical energy is delivered?

Step 1: Identify Knowns & Unknowns



- Knowns: $\Delta V = 6.0 \text{ V}$, $I = 0.50 \text{ A}$, $t = 5.0 \text{ min}$
- Unknowns: $P = ?$, $E = ?$

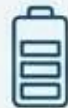
Step 2: Calculate Power (Part a)



$$P = I\Delta V$$

$$P = (0.50 \text{ A})(6.0 \text{ V}) = 3.0 \text{ W}$$

Step 3: Calculate Energy (Part b)



$$E = P * t$$

$$5.0 \text{ min} \times (60 \text{ s} / 1 \text{ min}) = 300 \text{ s}$$

$$E = (3.0 \text{ W})(300 \text{ s}) = 900 \text{ J} \text{ or } 9.0 \times 10^2 \text{ J}$$

Practice Problems: Apply Your Knowledge (Set 1)

Use the formula $P = I\Delta V$ to solve the following.

1. A car battery produces a potential difference of 12 V across a headlight. If the headlight draws a current of 2.5 A, what is the power used by the headlight?
2. What is the current through a 75 W lamp that is connected to a 125 V outlet?
3. A current of 0.50 A flows through a lamp connected to a 125 V source. At what rate does the lamp convert electrical energy into light and heat?

Practice Problems: Apply Your Knowledge (Set 2)

Use the formulas $P = I\Delta V$ and $E = P \cdot t$ to solve the following.

4. The starter motor of a car draws 210 A from the 12 V battery. How much electrical energy is delivered to the starter in 10.0 seconds?
5. A 75 V generator provides 3.0 kW of power. How much current does the generator produce? (Hint: 1 kW = 1000 W)
6. A flashlight bulb is rated for 0.90 W. If the potential difference across it is 3.0 V, what is the current through the bulb?

Challenge Yourself & Key Takeaways

Challenge Problem":

The voltage across a motor is doubled, and the current through it is tripled. By what factor does the power delivered to the motor change?

(Answer hint: Think about the relationship in $P = I\Delta V$. The new power will be $(3I) \times (2\Delta V)$.)

- **Electric Current** is the rate of flow of charge, driven by a potential difference (voltage). $I = q / t$
- **Electric Circuits** are closed loops that allow for the transfer and conversion of energy.
- **Power** is the rate of energy transfer, calculated by multiplying current and voltage. $P = I\Delta V$

The Blueprint of Electricity

A Comprehensive Guide to Electric Circuits & Ohm's Law



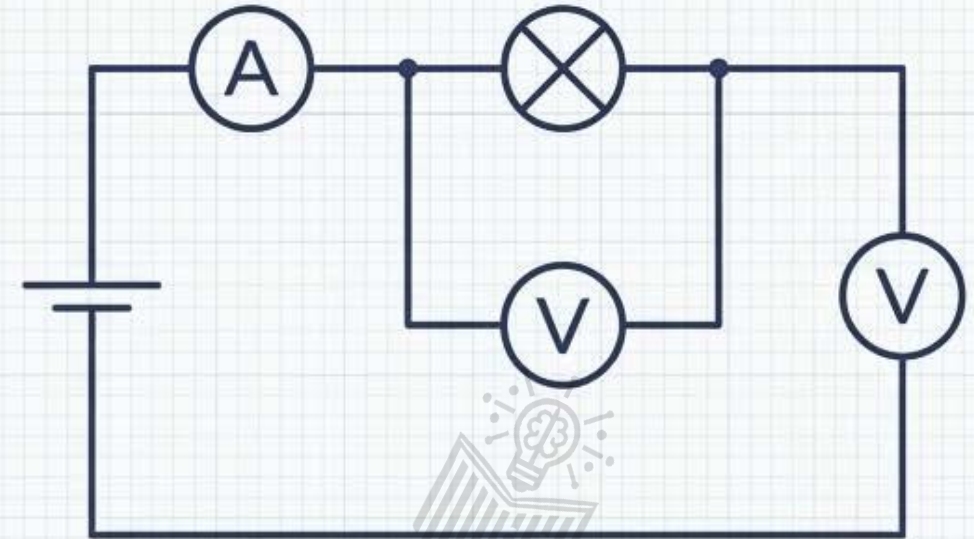
Presented by Mr. Mohamad

From Physical Wires to Universal Language

We can describe a circuit with words or photos, but for clarity and precision, physicists use a universal language: the schematic diagram. A schematic uses simple, standard symbols to represent each component, making any circuit easy to read and analyze.



The Real World



The Schematic Language

The Alphabet of Electricity: Essential Circuit Symbols

Every component in a circuit has a unique symbol. Mastering these symbols is the first step to understanding and building circuits.



Battery



Resistor (fixed)



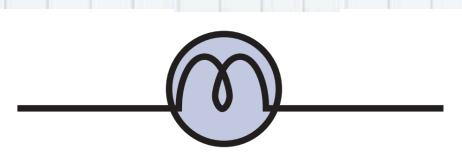
Potentiometer
(variable resistor)



inductor



Switch



Lightbulb



Ammeter



Voltmeter



Wire (Conductor)



Ground



Fuse



Capacitor

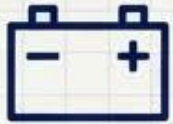


DC Generator

How to Draw a Schematic: A 5-Step Strategy

Follow these steps to translate any physical circuit into a clear schematic diagram.

1.



1. Start with the Source

Draw the battery or power source on the left, with the positive (+) terminal on top.

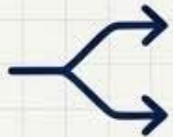
2.



2. Trace the Path

Draw the wire leaving the positive terminal. When you encounter a component (like a resistor), draw its symbol.

3.



3. Handle Branches

If the current splits into multiple paths, draw the split. Follow one path completely until it rejoins the main circuit, then draw the other path.

4.



4. Complete the Loop

Continue tracing the path until you return to the negative (-) terminal of the power source.

5.



5. Final Check

Review your diagram. Ensure all components are included and there is a complete, unbroken path for the current to flow.

Your Turn: Practice Drawing These Circuits

Use the 5-step strategy to draw a schematic diagram for each of the following descriptions.

Problem 1

Draw a circuit with a 60.0 V battery, an ammeter, and a $12.5\ \Omega$ resistor, all connected in series. Indicate the direction of conventional current with arrows.

Problem 2

Draw a circuit showing a 4.5 V battery and a resistor. An ammeter in the circuit reads 85 mA. Show the conventional current direction and label the positive terminal of the battery.

Problem 3

Modify your diagrams for the two problems above to include a voltmeter that measures the voltage across each resistor.

Problem 4

Draw a circuit with a battery, a lamp, a switch to turn it on/off, and a potentiometer to control the lamp's brightness. Then, add an ammeter to measure the current through the lamp and a voltmeter to measure the voltage across it.

The Three Pillars of a Circuit



Potential Difference (Voltage)

Symbol: ΔV
Unit: Volt (V)

Definition: The 'push' or electrical pressure that causes charge to flow.

Measured By: A **Voltmeter**, which measures the voltage across two points in a circuit.



Electric Current

Symbol: I
Unit: Ampere (A)

Definition: The rate of flow of electric charge.

Measured By: An **Ammeter**, which measures the current flowing through a point in a circuit.



Resistance

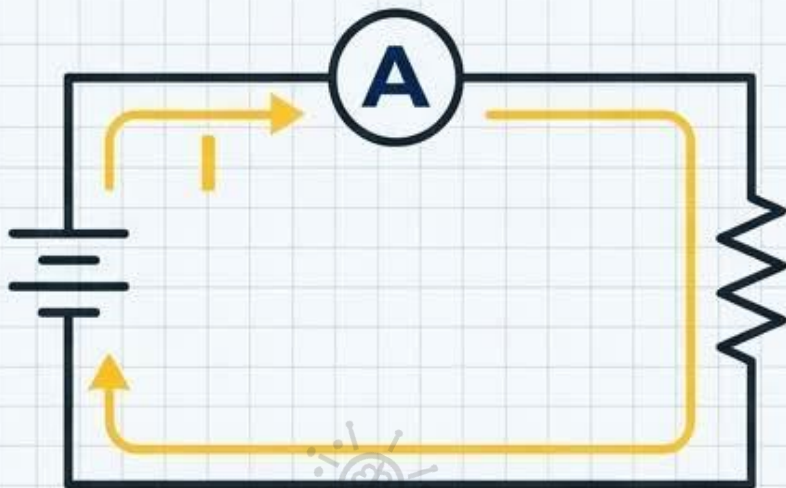
Symbol: R
Unit: Ohm (Ω)

Definition: The opposition to the flow of current.

Connecting Your Meters: Series vs. Parallel

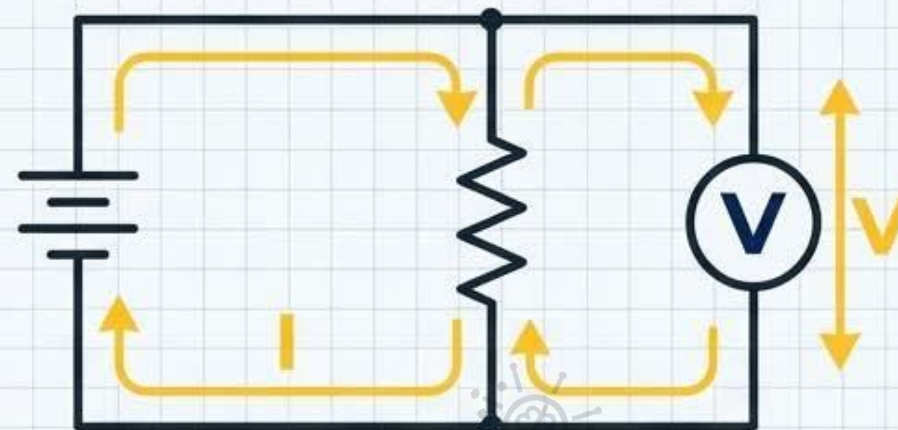
The way you connect a meter is critical. An ammeter must be part of the path, while a voltmeter must bridge two points.

Series: For Measuring Current (Ammeters)



There is only one path for the current. Always associate **current *through*** with a **series** connection.

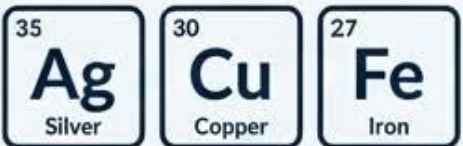
Parallel: For Measuring Voltage (Voltmeters)



The current splits into two or more paths. Always associate **voltage *across*** with a **parallel** connection.

What Determines a Material's Resistance?

Resistance is the measure of how strongly a material opposes the flow of electric current. Four key factors determine the resistance of a conductor.

Factor	Icon	Explanation
Length (L)		Resistance increases as length increases.
Cross-Sectional Area (A)		Resistance increases as area decreases.
Temperature (T)		For most conductors, resistance increases as temperature increases.
Material Type (ρ)		Different materials have inherently different resistances (e.g., silver has less resistance than iron).

Physics in Real Life: A 100W light bulb's tungsten filament has a resistance of about **10 Ω** when cold, but it rises to **140 Ω** when hot and operating!

The Unbreakable Rule: Ohm's Law

In the 19th century, Georg Ohm discovered a fundamental relationship between voltage, current, and resistance. Ohm's Law states that the current through a conductor is directly proportional to the voltage across it.

Ohm's Law

$$R \equiv \Delta V / I$$

Resistance (R) is defined as the ratio of the potential difference (ΔV) to the current (I).

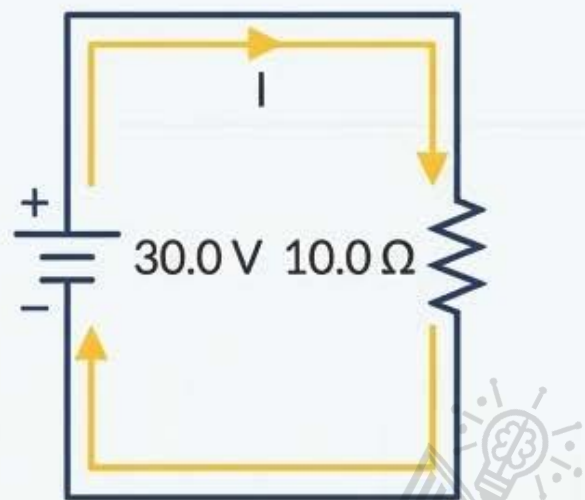
$$1 \text{ Ohm } (\Omega) = 1 \text{ Volt (V)} / 1 \text{ Ampere (A)}$$

**Devices that have a constant resistance are said to obey Ohm's Law. This includes most metal wires. However, components like transistors and diodes do not.*

Ohm's Law in Action: A Worked Example

Problem: A 30.0 V battery is connected to a 10.0 Ω resistor. What is the current in the circuit?

1. Analyze & Sketch



2. List Knowns & Unknowns

Known:

$$\Delta V = 30.0 \text{ V}$$

$$R = 10.0 \Omega$$

Unknown:

$$I = ?$$

3. Calculate

Use Ohm's Law:

$$I = \frac{\Delta V}{R}$$

Substitute values:

$$I = \frac{30.0 \text{ V}}{10.0 \Omega}$$

$$I = 3.00 \text{ A}$$

4. Evaluate

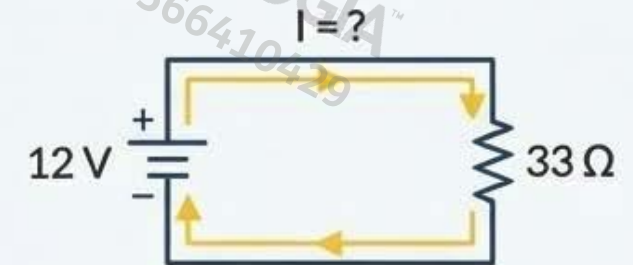
✓ **Units:** The answer is in Amperes, the correct unit for current.

✓ **Magnitude:** A relatively large voltage and low resistance results in a reasonably large current of 3.00 A. The answer is logical.

Your Turn: Master the Calculations (Set 1)

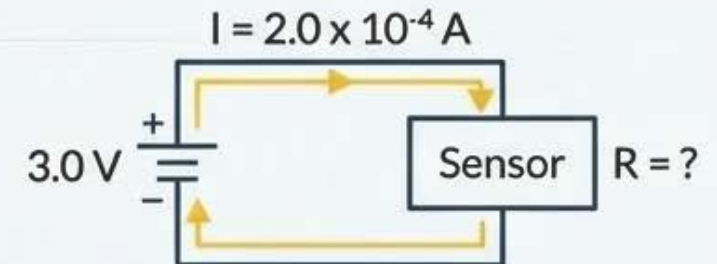
For each problem, calculate the unknown value. Assume all components are constant.

Problem 1: A car's dashboard light has a resistance of $33\ \Omega$ and is connected across the 12 V battery shown. What is the current flowing through it?



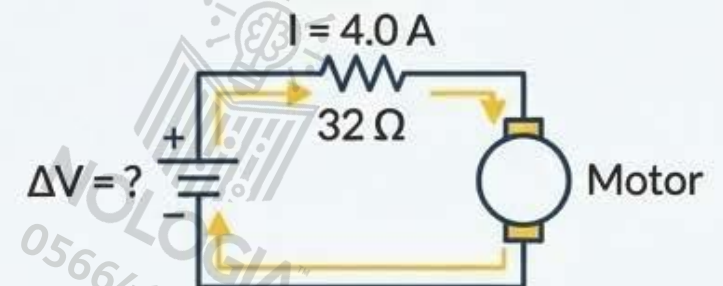
الشكل 11

Problem 2: A sensor draws $2.0 \times 10^{-4}\text{ A}$ of current when operated by the 3.0 V battery shown. What is the resistance of the sensor circuit?



الشكل 12

Problem 3: A motor with an operating resistance of $32\ \Omega$ is connected to the voltage source shown, drawing 4.0 A . What is the voltage of the source?



الشكل 13

Your Turn: Master the Calculations (Set 2)

Solve the following multi-part problems.

Problem 4: A lamp draws a current of 0.50 A when connected to a 120 V source.

- What is the resistance of the lamp?
- What is the power consumption of the lamp?

Problem 5: A 75 W light bulb is connected to a 125 V source.

- What is the current flowing through the bulb?
- What is the resistance of the bulb?



Challenge!

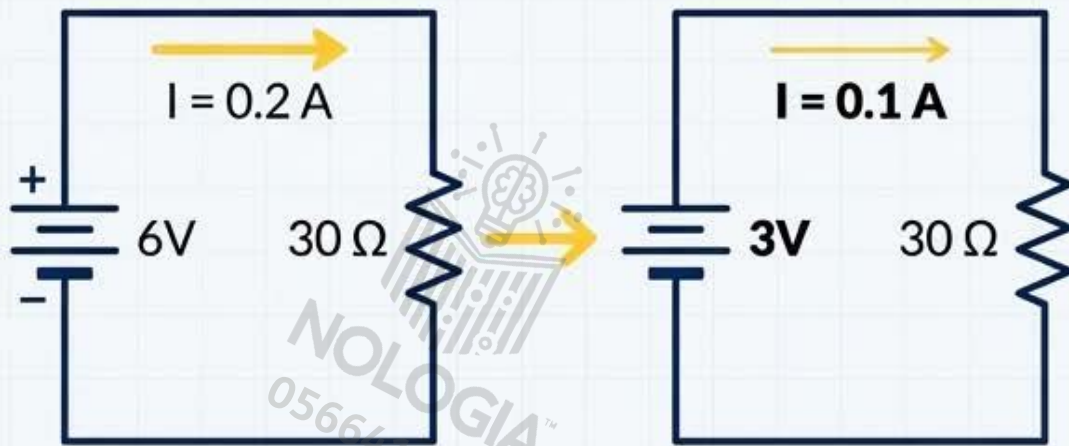
A resistor is added in series with the bulb from Problem 5 to reduce the current to half its original value. How much resistance was added to the circuit?

Controlling the Flow: Two Ways to Adjust Current

According to Ohm's Law ($I = \Delta V / R$), there are only two ways to control the current in a simple circuit.

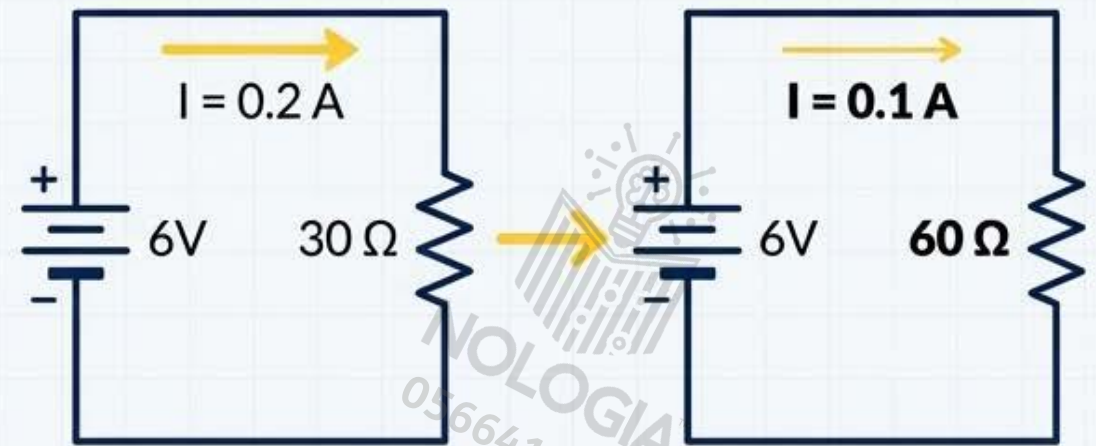
Change the Voltage (ΔV)

 If you decrease the voltage while keeping resistance constant, the current will decrease.



Change the Resistance (R)

 If you increase the resistance while keeping voltage constant, the current will decrease.



For Smooth Control: The Potentiometer

A potentiometer is a type of variable resistor. By moving a sliding contact, you change the length of the resistive wire in the circuit. This allows for continuous, fine-tuned control over the resistance and, therefore, the current.



More wire in the circuit means higher resistance and a slower motor.



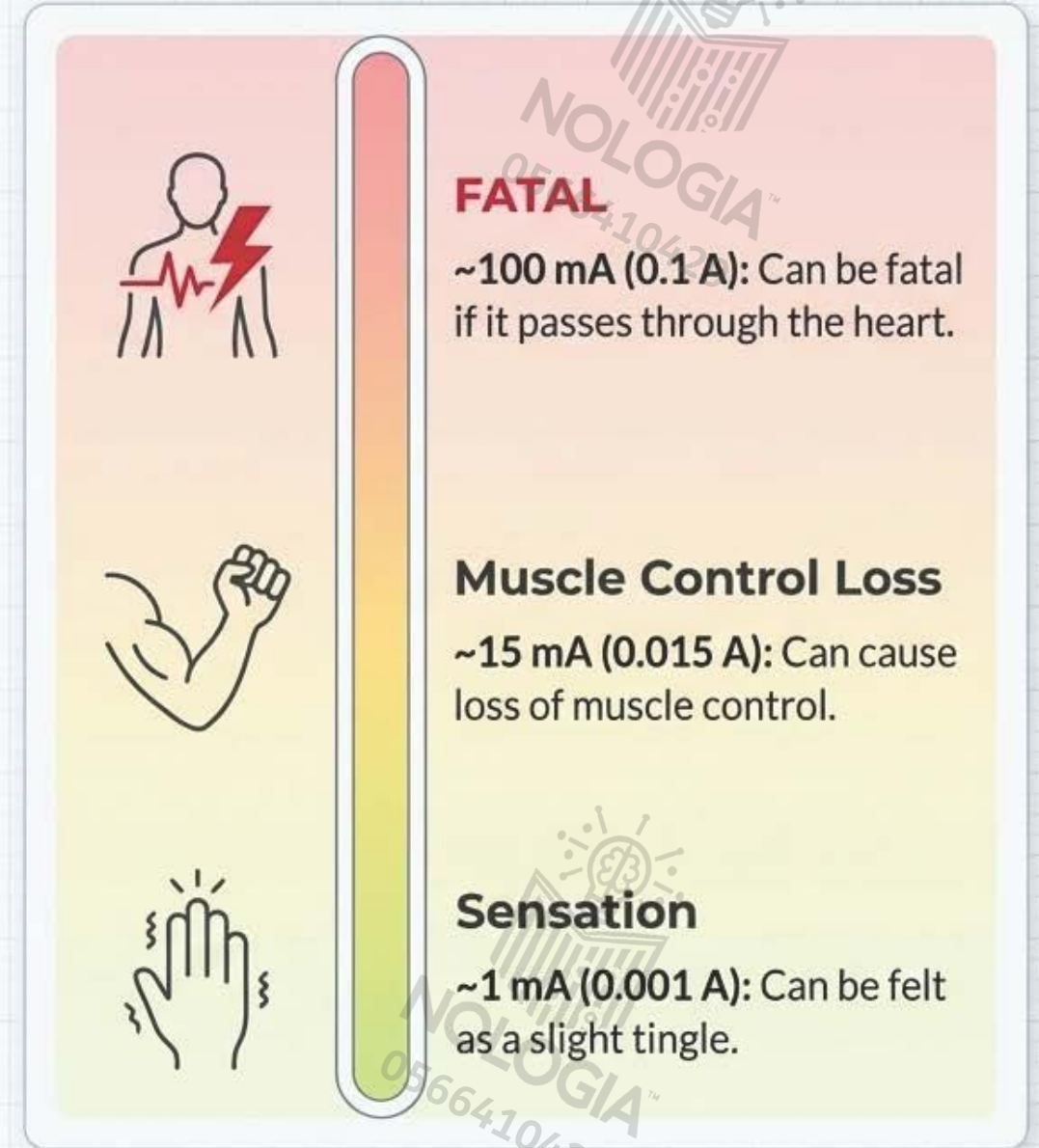
Analog joysticks use potentiometers to translate physical movement into electrical signals that a computer can understand.



A Critical Warning: Your Body and Electrical Current

The human body acts as a resistor. While dry skin has a high resistance, wet skin's resistance drops dramatically, allowing dangerous levels of current to flow even at lower voltages.

Always treat electricity with caution.



The Blueprint: Your Summary & Key Formulas

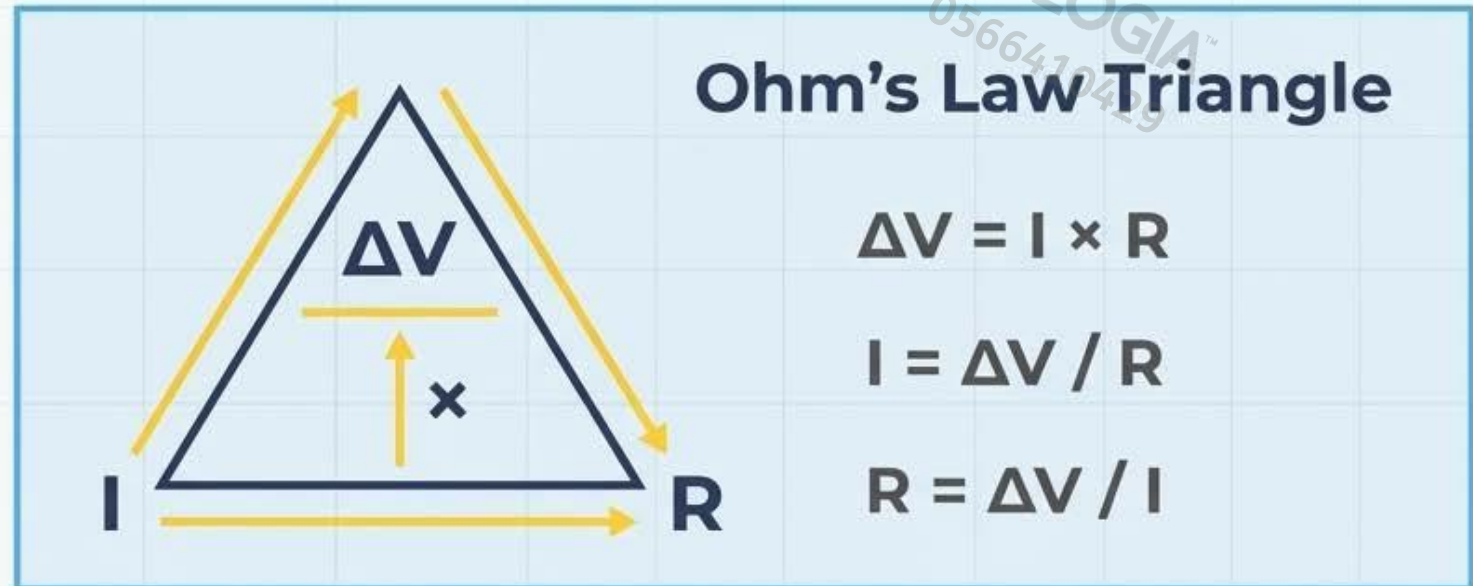
Key Concepts

- Series Connection**

Single path for current (I).
Ammeters connect in series.

- Parallel Connection**

Multiple paths for current.
Voltsmeters connect across components in parallel.



Essential Symbols Review



Battery



Resistor



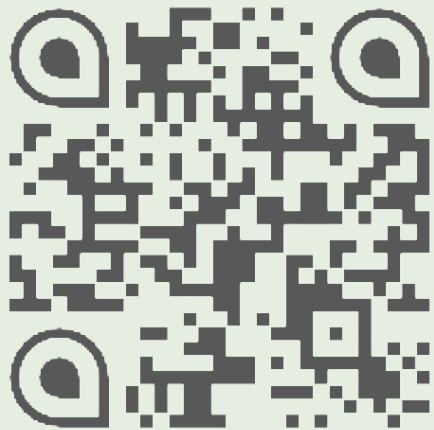
Switch



Ammeter



Voltmeter



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Unit (3): Electric Current

02

Second Section: Using Electrical Energy



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Harnessing Electricity: A Comprehensive Guide to Power & Energy

Presented by Mr. Mohamad



Energy is Never Lost, Only Transformed

Ever wonder why your phone charger or a light bulb gets warm?



Radiant Energy

Electrical energy is converted into light from a bulb.



Mechanical Energy

Electrical energy is converted into the motion of a fan's blades.



Thermal Energy

Electrical energy is converted into heat from a resistive coil.

Key Insight

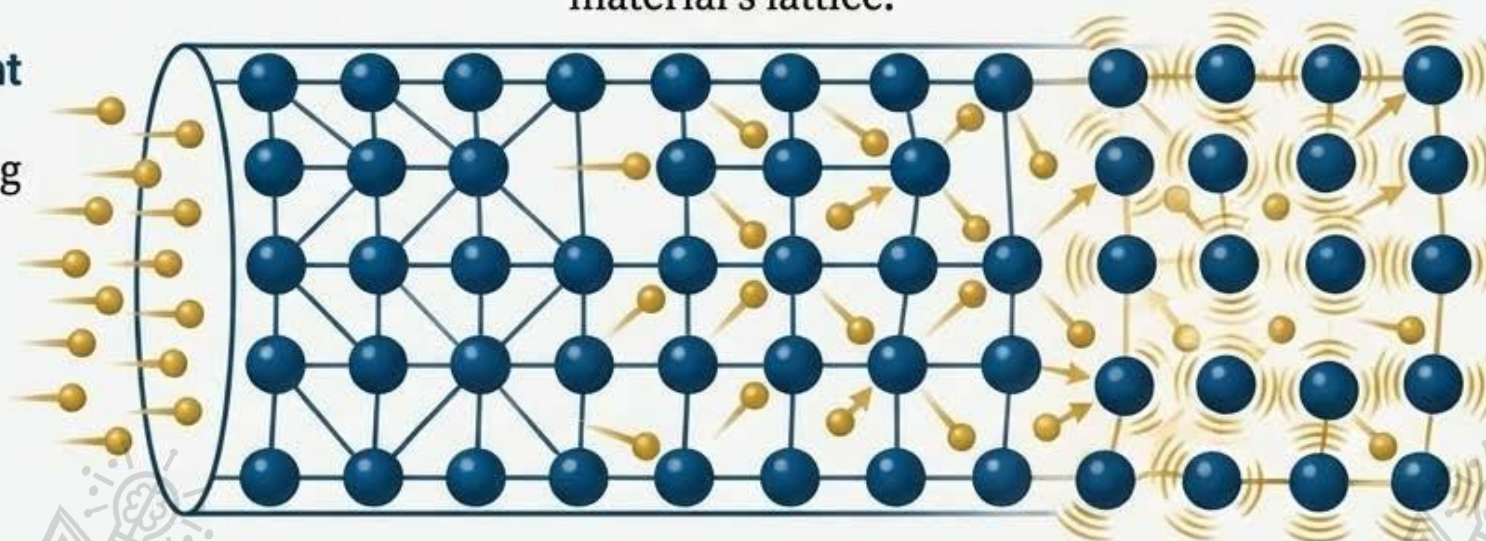
Unfortunately, **not all energy supplied to a device ends up in a useful form**. In many cases, especially with incandescent bulbs, a significant portion of the electrical energy is converted into **thermal energy** (heat) as a byproduct.

The Source of Heat: A Microscopic View

How is electrical energy converted into thermal energy?

The moving electrons **collide** with the atoms that make up the material's lattice.

An **electric current** flows. Electrons (small, fast-moving gold spheres) are introduced from the left.



These collisions transfer **kinetic energy**, causing the atoms to vibrate intensely. This increased atomic vibration is what we perceive as **heat**.

This process is the fundamental reason why components with **electrical resistance heat up**. Devices like space heaters, heating plates, and hair dryers are specifically designed with high-resistance materials to maximize this effect and efficiently convert electrical energy into thermal energy.

Quantifying the Flow: The Definition of Power

While energy (E) is the total amount supplied, what's often more important is the **rate** at which that energy is transformed. This rate is called **Power (P)**.

Power and Energy

$$P = E / t$$

(Power = Energy transformed / time)

The Fundamental Power Equation

Power is also the product of the current (I) flowing through a component and the potential difference (ΔV) across it.

$$P = I \Delta V$$



P:
Power, measured
in **Watts (W)**



I:
Current, measured
in **Amperes (A)**



ΔV :
Potential Difference
(Voltage), measured
in **Volts (V)**

The Power Triangle: Three Essential Formulas

By combining the fundamental power equation ($P = I\Delta V$) with Ohm's Law ($\Delta V = IR$), we can derive two other powerful formulas.

The Fundamental Relationship

$$P = I\Delta V$$

Use When

You know the current and voltage.

Power from Current & Resistance

$$P = I^2R$$

Derivation

Substitute $\Delta V = IR$ into
 $P = I\Delta V \rightarrow P = I(IR) = I^2R$

Use When

You know the current and resistance.
 The rate of energy conversion is proportional to the square of the current.

Power from Voltage & Resistance

$$P = (\Delta V)^2/R$$

Derivation

Substitute $I = \Delta V/R$ into
 $P = I\Delta V \rightarrow P = (\Delta V/R)\Delta V = (\Delta V)^2/R$

Use When

You know the voltage and resistance.

Worked Example: The Electric Heater



An electric heater has a resistance of $10.0 \, \Omega$ and operates at a voltage of $120.0 \, \text{V}$.

- What is the power of the heater?
- How much thermal energy does it produce in $10.0 \, \text{s}$?

Step 1: Analyze & Identify Knowns/Unknowns

Knowns:

$$R = 10.0 \, \Omega$$

$$\Delta V = 120.0 \, \text{V}$$

$$t = 10.0 \, \text{s}$$

Unknowns:

$$\text{Power } (P) = ?$$

$$\text{Energy } (E) = ?$$

Step 2: Solve for Power (a)

Select Formula: We know ΔV and R , so we use $P = (\Delta V)^2 / R$.

$$\text{Calculation: } P = (120.0 \, \text{V})^2 / 10.0 \, \Omega = 1440 \, \text{W}$$

$$\text{Final Answer: } 1.44 \, \text{kW}$$

Step 3: Solve for Energy (b)

Select Formula: Energy is power multiplied by time: $E = Pt$.

$$\text{Calculation: } E = (1440 \, \text{W}) \times (10.0 \, \text{s}) = 14,400 \, \text{J}$$

$$\text{Final Answer: } 14.4 \, \text{kJ}$$

Step 4: Evaluate the Answer

The units (Watts for power, Joules for energy) are correct. The magnitudes are reasonable for a common heating appliance.

Challenge Time: Mastering Appliance Calculations

Problem 1 (Based on #26) A $15\ \Omega$ electric heater operates on a 120 V outlet.



- What is the current flowing through the heater?
- How much power does it dissipate?

$$\text{a. } I = \frac{\Delta V}{R} = \frac{120\text{ V}}{15\ \Omega} = \mathbf{8.0\text{ A}}$$

$$\text{b. } P = I\Delta V = (8.0\text{ A})(120\text{ V}) = \mathbf{960\text{ W}}$$

Problem 2 (Based on #27) A $39\ \Omega$ resistor is connected to a 45 V battery.



- What is the current in the circuit?
- How much energy is used by the resistor in 5.0 minutes?

$$\text{a. } I = \frac{\Delta V}{R} = \frac{45\text{ V}}{39\ \Omega} \approx \mathbf{1.2\text{ A}}$$

$$\text{b. First, find Power: } P = I^2 R = (1.15\text{ A})^2 (39\ \Omega) \approx 51.5\text{ W.}$$

$$\text{Then find Energy: } E = Pt = (51.5\text{ W})(300\text{ s}) \approx \mathbf{15,000\text{ J or }15\text{ kJ}}$$

(Note: 5.0 min = 300 s)

Deeper Dive: Energy, Heat, and Efficiency

Problem Statement (Based on #28): A 100.0 W light bulb is 22% efficient. This means 22% of the electrical energy is converted to radiant (light) energy. In one minute of operation:

- How many joules are converted to radiant energy?
- How many joules of thermal energy does the bulb release?

Step 1: Calculate Total Energy Used

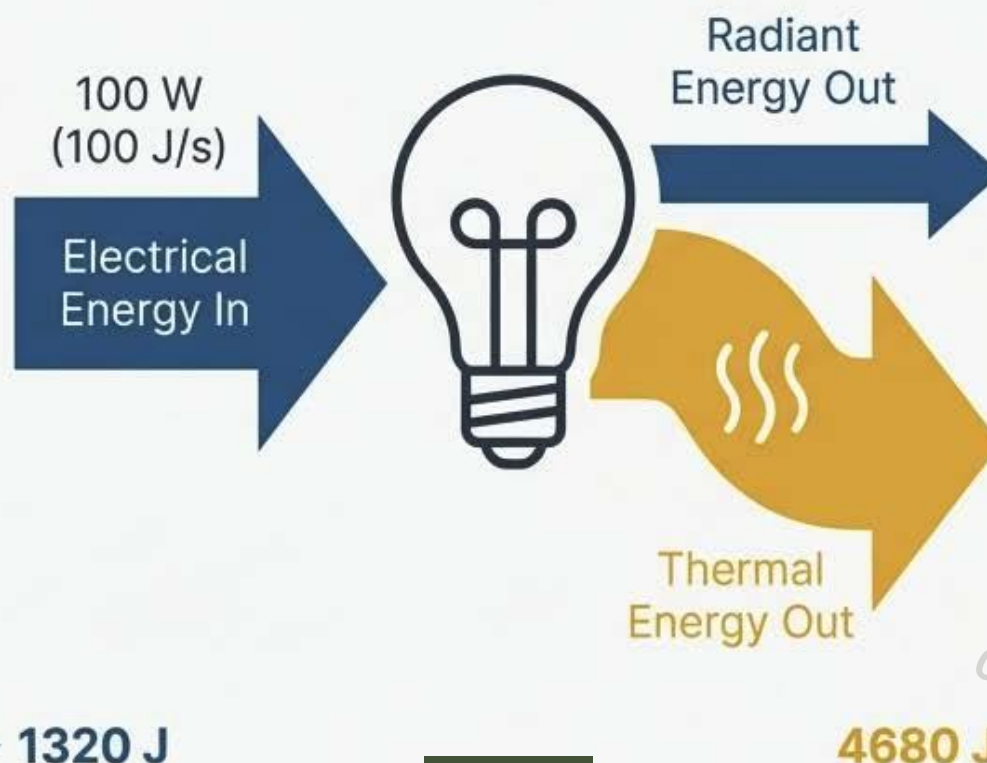
The bulb's power rating is 100.0 W (100 J/s). Time is 1 minute = 60 s.

$$\text{Total Energy } (E_{\text{total}}) = P \times t \\ = 100.0 \text{ J/s} \times 60 \text{ s} = \mathbf{6000 \text{ J}}$$

Step 2: Calculate Radiant Energy (a)

Use the efficiency percentage (22% = 0.22).

$$\text{Radiant Energy} = E_{\text{total}} \times 0.22 \\ = 6000 \text{ J} \times 0.22 = \mathbf{1320 \text{ J}}$$



Step 3: Calculate Thermal Energy (b)

The remaining energy is converted to heat.

$$\text{Thermal Energy} = E_{\text{total}} - \text{Radiant Energy} \\ = 6000 \text{ J} - 1320 \text{ J} \\ = \mathbf{4680 \text{ J}}$$

Alternatively:

$$\text{Thermal Energy} = E_{\text{total}} \times (1 - 0.22) \\ = 6000 \text{ J} \times 0.78 = \mathbf{4680 \text{ J}}$$

Practice Your Skills: A Comprehensive Problem Set

Use the power and energy formulas to solve the following problems.
(Answers can be found in the appendix or at the end of the presentation).

#29



An $11\ \Omega$ oven element is connected to 220 V. Find: (a) the current, (b) the energy converted in 30.0 s, and (c) the temperature increase of 1.20 kg of water that absorbs 65% of this energy.

#31



A 15.0 A heater runs on a 120 V source for 5.0 hours a day. Find: (a) its power, (b) its energy consumption in kWh for 30 days, and (c) the cost at 0.30 AED/kWh.

#32



A digital clock with $12,000\ \Omega$ resistance is plugged into a 115 V outlet. Find: (a) the current it draws, (b) the power it uses, and (c) the cost to run it for 30 days.

#40



A toaster connected to a 120 V circuit draws 4.2 A of current. Find: (a) its resistance and (b) its power rating.



The Big Picture: The Challenge of Transmitting Power

The Problem

Power plants can generate enormous amounts of energy. But how do we transport it over hundreds of kilometers to homes and factories with minimal waste?

The Enemy: Joule Heating

Electrical energy is converted to thermal energy in transmission wires at a rate given by the formula:

$$P_{\text{loss}} = I^2 R$$

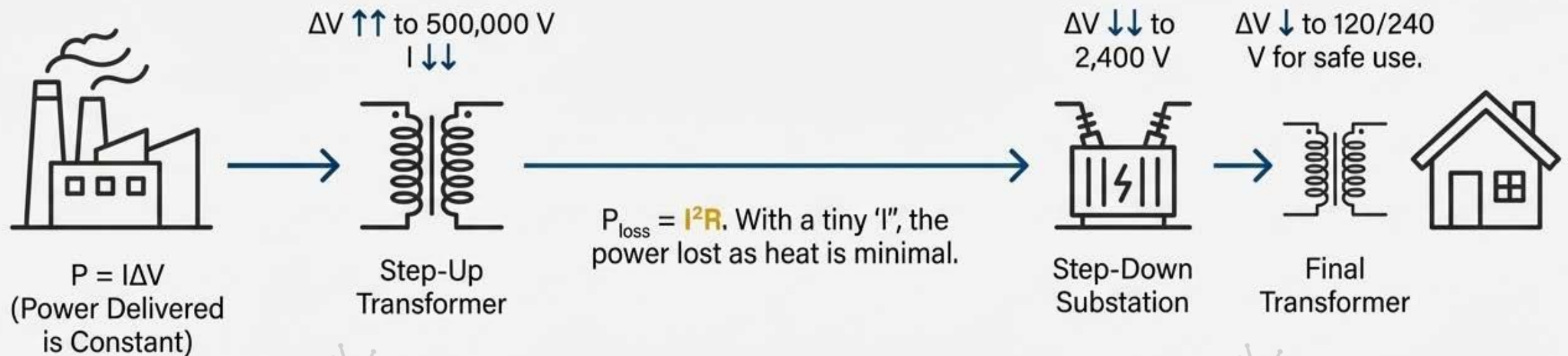
This unwanted heating is called **Joule Heating** or **$I^2 R$ Loss**.

To reduce this loss, engineers must minimize either the current (I) or the resistance (R) of the wires.

The Challenge with Resistance (R)

While using thick, highly conductive cables reduces resistance, they are extremely expensive and heavy, making this solution impractical for a national grid.

The Elegant Solution: High Voltage, Low Current



The Strategy: To deliver the same amount of power (P), we dramatically **increase the voltage (ΔV)**. This allows us to dramatically **decrease the current (I)**. Since power loss is proportional to the **square of the current (I^2)**, this leads to a massive reduction in energy wasted as heat.

The Future of Transmission: Superconductors

The Concept

A **superconductor** is a material with zero electrical resistance ($R = 0$).

The Implication

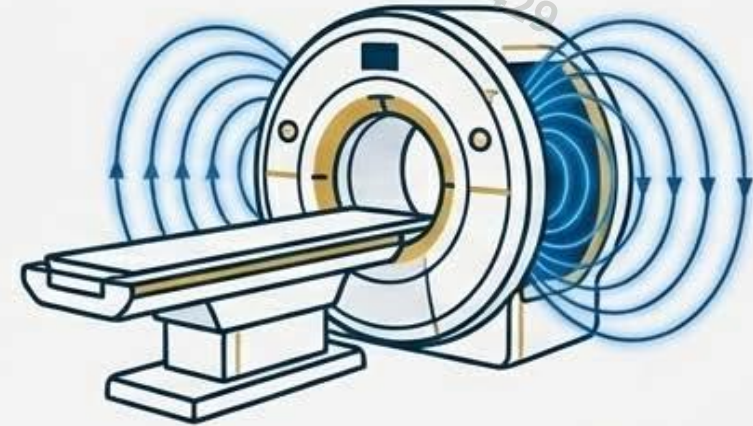
If resistance is zero, then the power lost to heat is also zero.

$$P_{loss} = I^2 R = I^2(0) = 0$$

The Promise

Superconducting cables could transmit electricity with 100% efficiency, with no energy converted to thermal energy.

The Challenge & Application



The Current Challenge

Today, all known practical superconductors must be kept at extremely low **temperatures (below 100 K or -173 °C)** to function.

Current Applications

This technology is currently used in specialized applications like powerful magnets for Magnetic Resonance Imaging (MRI) machines.

The Bottom Line: You Pay for Energy, Not Power

Utility companies are often called “power companies,” but what they actually sell you is **energy**.

Power (Watts)



The **rate** at which energy is used. Think of it like the **speed** of your car (km/h).

Your electricity bill reflects the total amount of electrical energy you consumed over a month, not the peak rate at which you used it.

Energy (Joules or kWh)



The *total quantity* of work done. Think of it like the **total distance** you traveled (km).

The Language of Your Bill: The Kilowatt-Hour (kWh)

The Problem with Joules

The joule is a tiny unit. Billing in joules would involve astronomically large and impractical numbers.

The Practical Solution

Companies measure energy sales in a much larger unit: the **kilowatt-hour (kWh)**,

What is a kWh?

One kWh is the energy consumed when **1000 watts** of **power** are used for **one hour**.

💡 $1 \text{ kWh} = 1000 \text{ W} \times 3600 \text{ s} = 3.6 \times 10^6 \text{ Joules}$

Calculating Your Cost

📄 $\text{Cost} = \text{Energy Used (kWh)} \times \text{Rate (Price per kWh)}$

Example:

- Energy Used: 2705 kWh
- Rate: 0.077 AED/kWh
- Cost = $2705 \times 0.077 = 208.29 \text{ AED}$

Key Takeaways: From Electron Collisions to Your Electric Bill



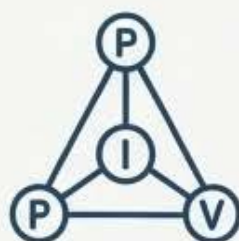
1. Energy in Motion

Electrical energy is transformed into useful work and heat, driven by electron collisions within a material.



3. Efficient Transmission

To minimize energy loss (I^2R) over long distances, power is transmitted at three key formulas: $P = I\Delta V$, $P = I^2R$, and $P = (\Delta V)^2/R$.



2. The Language of Power

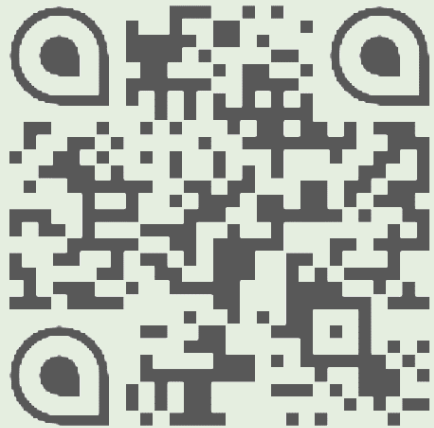
To minimize energy loss (I^2R) over long distances, power is transmitted at very high voltages to reduce the current.



4. Paying for Energy

We purchase a quantity of energy from utility companies, measured in a practical unit called the **kilowatt-hour (kWh)**.

You now have the tools to analyze any circuit and understand the flow of energy that powers our world.



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قم بمسح رمز الـ QR

Unit (3): Electric Current

Unit Revision: Electric Current

لحجز مقعدك قم بالتواصل معنا
اضغط هنا: 0566410429

Mastering Electric Current & Energy

A Comprehensive Study Guide

Presented by
Mr. Mohamad

Why This Matters: Powering Our Modern World

Today, we depend entirely on electrical energy. Understanding how it works is essential. The future is the "Smart Grid"—an intelligent network designed to be more efficient, reliable, and sustainable.



Efficiency

Tools to help consumers reduce energy consumption.



Reliability

Quickly detects and repairs power outages.



Affordability

Improvements make electricity more cost-effective.



Security

Resistant to natural and man-made incidents.



Sustainability

Easily integrates clean energy sources like solar and wind.



The Language of Electricity: Core Concepts

Electric currents transfer energy which can be converted into other forms. A circuit is the path for this energy transfer.

Electric Current (I)

The flow of electric charge. Its direction is defined as the direction a positive charge would move (Conventional Current). Unit: Ampere (A).

Voltage (ΔV)

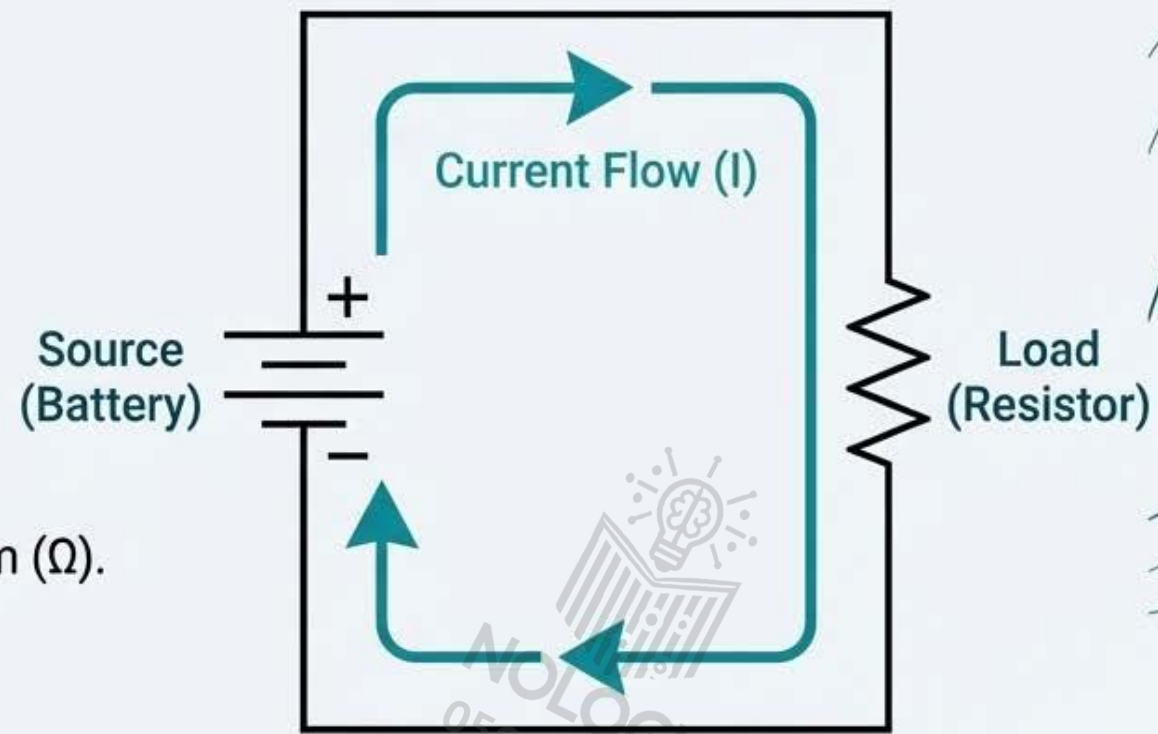
The potential difference that drives the current. Provided by a source like a battery. Unit: Volt (V).

Resistance (R)

The opposition to the flow of current. Components designed to have resistance are called resistors. Unit: Ohm (Ω).

Electric Circuit

A closed loop path that allows electric current to flow, typically containing a source (battery), a load (resistor/device), and conductors (wires).



The Fundamental Rule: Ohm's Law

For a given conductor, the ratio of the potential difference (Voltage) to the electric current is a constant value, which we call Resistance.

The Formula section

$$R = \Delta V / I$$

(Resistance = Voltage / Current)

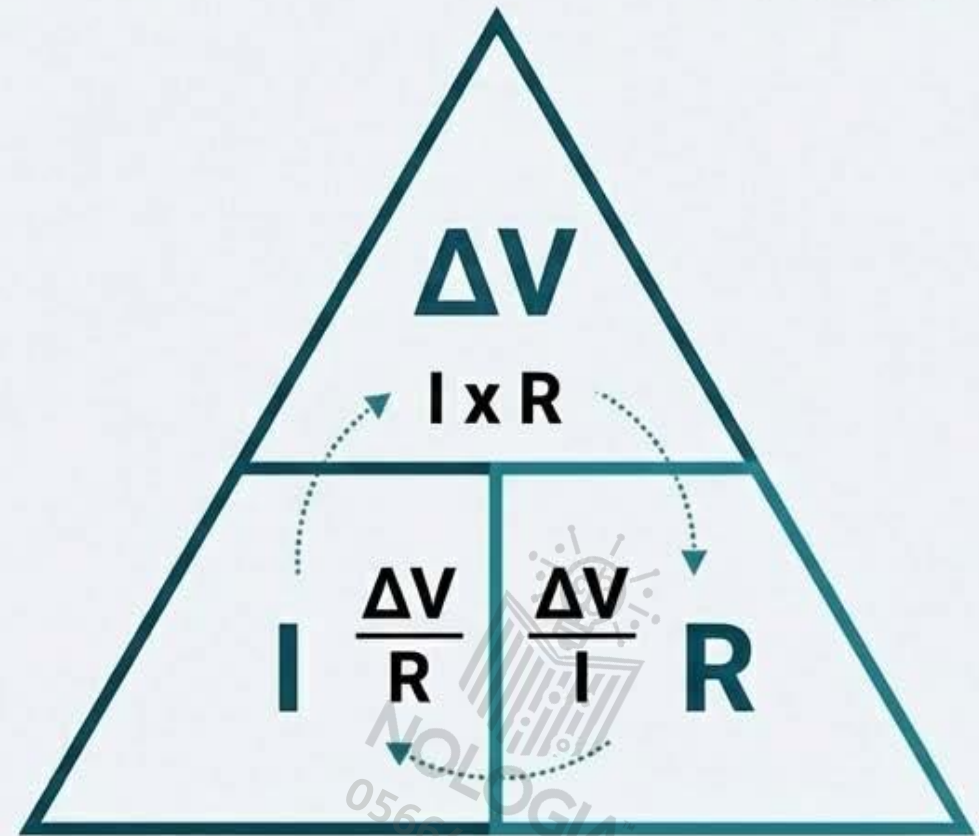
This can be rearranged to:

$$\Delta V = I * R$$

(Voltage = Current * Resistance)

Key Takeaway

Any resistor that follows this rule (where resistance doesn't change with voltage or current direction) is said to obey Ohm's Law.



Example Set 1: Applying Ohm's Law

Problem 1 (Source Q61)

A $60.0\ \Omega$ resistor has a current of $0.40\ \text{A}$ flowing through it when connected to a battery. What is the battery's voltage?

Solution:

$$\begin{aligned}\Delta V &= I * R \\ &= (0.40\ \text{A}) * (60.0\ \Omega) \\ &= \mathbf{24\ \text{V}}\end{aligned}$$

Problem 2 (Source Q62)

What voltage must be used with a $15\ \Omega$ resistor if the current needs to be $4.0\ \text{A}$?

Solution:

$$\begin{aligned}\Delta V &= I * R \\ &= (4.0\ \text{A}) * (15\ \Omega) \\ &= \mathbf{60\ \text{V}}\end{aligned}$$

Problem 3 (Source Q64)

What is the current in a $150\ \Omega$ resistor when a voltage of $75\ \text{V}$ is applied?

Solution:

$$\begin{aligned}I &= \Delta V / R \\ &= 75\ \text{V} / 150\ \Omega \\ &= \mathbf{0.50\ \text{A}}\end{aligned}$$

Part 2: The Work of Electricity - Power

Core Concept:

Electrical energy can be converted into other forms, such as heat, light, and mechanical motion. Electric Power (P) is the rate at which this energy conversion happens.

Definition:

Power is the energy converted per unit of time.

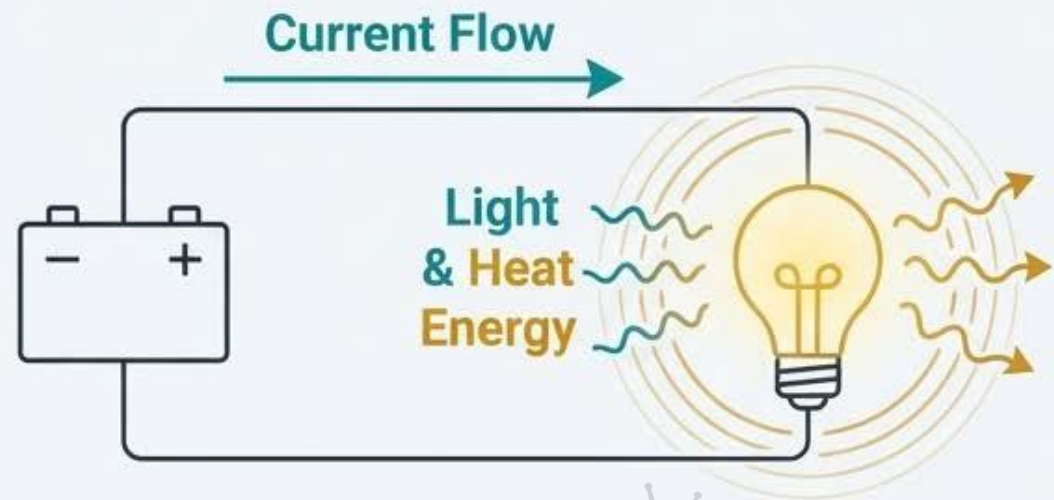
The Formula:

$$P = I * \Delta V$$

(Power = Current * Voltage)

Unit:

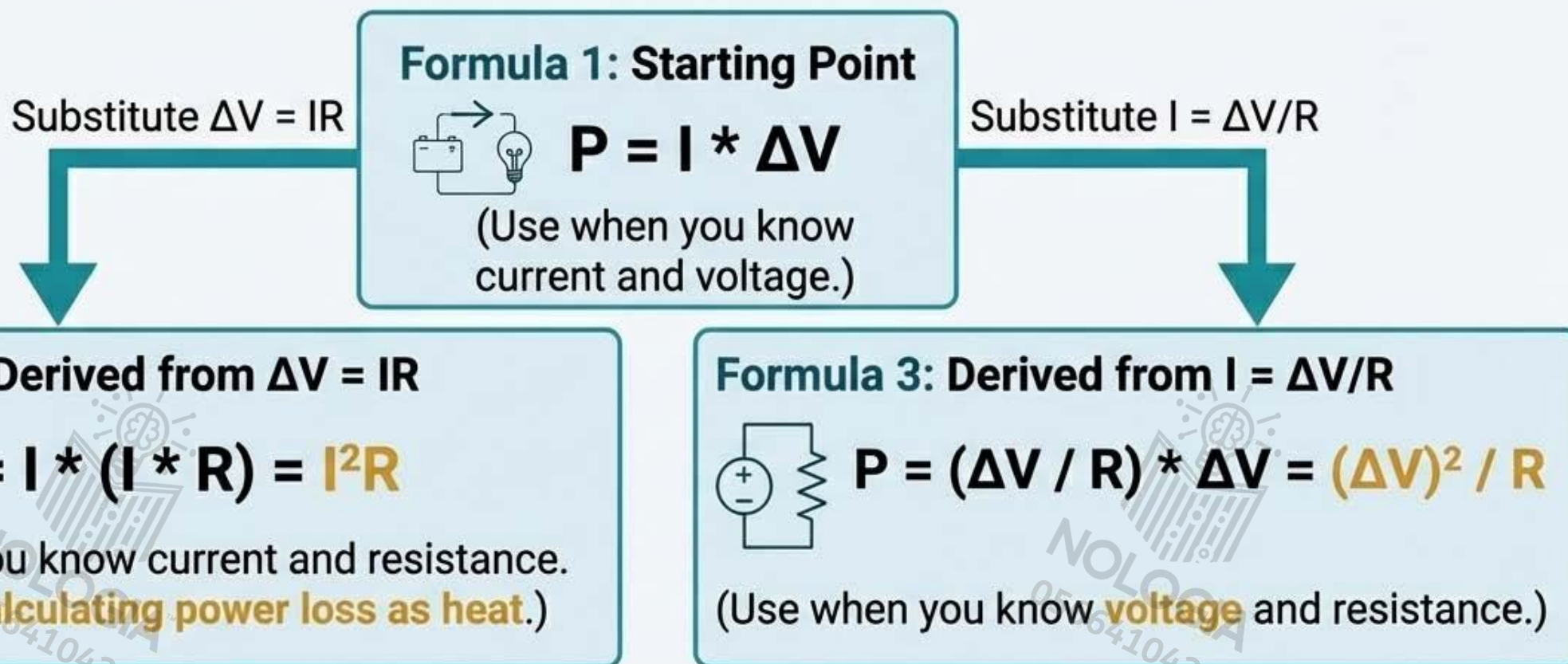
The SI unit for Power is the Watt (W).



Power (W): The rate of this conversion

The Power Toolkit: Three Essential Formulas

By substituting Ohm's Law ($\Delta V = IR$) into the main power equation ($P = I\Delta V$), we can derive two other useful formulas.



Example Set 2: Calculating Power



Problem 1: Toaster (Source Q53)

An electric toaster connected to a 120 V source draws a current of 8.0 A. How much power does it consume?

- Formula: $P = I * \Delta V$
- Solution: $P = (8.0 \text{ A}) * (120 \text{ V}) = \mathbf{960 \text{ W}}$



Problem 2: Light Bulb (Source Q57)

A lamp draws a current of 0.50 A from a 120 V generator.

- A) How much power is delivered?
 - Solution: $P = I * \Delta V = (0.50 \text{ A}) * (120 \text{ V}) = \mathbf{60 \text{ W}}$
- B) How much energy is converted in 5.0 min?
 - Solution: First, convert time to seconds: $5.0 \text{ min} * 60 \text{ s/min} = 300 \text{ s}$. Then, $E = P * t = (60 \text{ W}) * (300 \text{ s}) = \mathbf{18,000 \text{ J}}$ or $\mathbf{18 \text{ kJ}}$.

From Power to Energy: Total Consumption

Core Concept: If power is the rate of energy use, then total energy (E) is simply power multiplied by the time (t) the device is running.

The Formulas:

$$E = P * t$$

This leads to derived forms:

$$E = I^2 R t$$

$$E = (\Delta V)^2 t / R$$

Units of Energy:

- The **Joule (J)**: The standard SI unit (1 Watt-second).
- The **Kilowatt-hour (kWh)**: A larger unit used by utility companies to measure energy consumption. 1 kWh is the energy used by a 1000 W device running for 1 hour.



Worked-Out Solution: A Multi-Step Problem

Problem (Source Q51): A motor is connected to a 12 V battery. When running for 15 minutes, it draws a current of 1.5 A (value inferred from similar problems for a complete example).

- A) What is the electrical power delivered to the motor?
- B) How much energy is converted during this time?

GIVEN

Voltage (ΔV) = 12 V

Current (I) = 1.5 A

Time (t) = 15 min

REQUIRED

A) Power (P) in Watts

B) Energy (E) in Joules

SOLUTION

Part A: Power

Formula: $P = I * \Delta V$

Calculation: $P = (1.5 \text{ A}) * (12 \text{ V}) = \mathbf{18 \text{ W}}$

Part B: Energy

Step 1: Convert time to seconds: $t = 15 \text{ min} * (60 \text{ s} / 1 \text{ min}) = 900 \text{ s}$

Formula: $E = P * t$

Calculation: $E = (18 \text{ W}) * (900 \text{ s}) = \mathbf{16,200 \text{ J}}$

Real-World Application: The Cost of Energy

Problem (Adapted from Q80): An air conditioner on a 120 V circuit costs about 50 AED to run for 30 days. It runs for half the day (12 hours/day) and the cost of electricity is 0.090 AED per kWh. What is the current drawn by the A/C?

Step 1: Find the total cost per hour of operation.

$$\text{Total hours} = 30 \text{ days} * 12 \text{ hours/day} = 360 \text{ hours}$$

$$\begin{aligned} \text{Cost per hour} &= 50 \text{ AED} / 360 \text{ hours} \\ &= 0.139 \text{ AED/hour} \end{aligned}$$



Step 2: Find the power in kW.

$$\text{Power (kW)} = \text{Cost per hour} / \text{Cost per kWh}$$

$$\begin{aligned} \text{Power (kW)} &= 0.139 \text{ AED/hr} / 0.090 \\ &\text{AED/kWh} = 1.54 \text{ kW} \end{aligned}$$



Step 3: Convert power to Watts.

$$\begin{aligned} \text{Power (W)} &= 1.54 \text{ kW} * 1000 \text{ W/kW} \\ &= 1540 \text{ W} \end{aligned}$$



Step 4: Calculate the current using $P = I\Delta V$.

$$I = P / \Delta V = 1540 \text{ W} / 120 \text{ V} = \mathbf{12.8 \text{ A}}$$



Advanced Topic: Does Everything Obey Ohm's Law?

Key Question: Is resistance always constant? **Answer: No.**

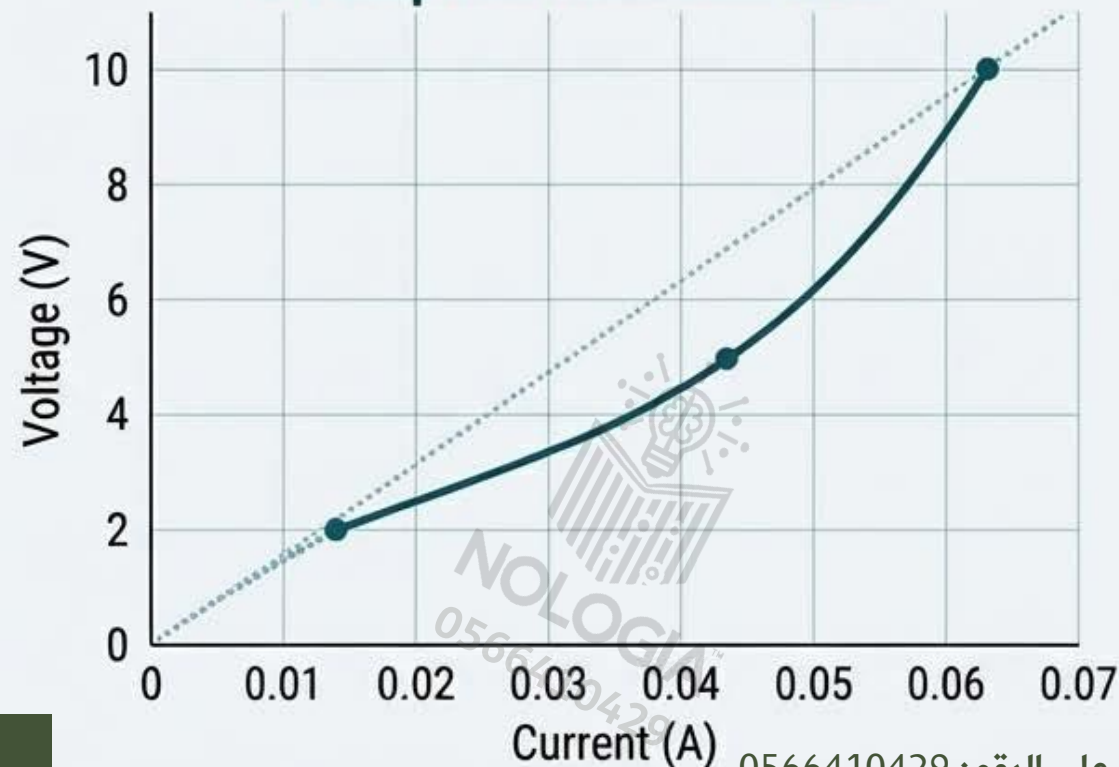
- Devices that follow Ohm's Law are called **ohmic**. Their V-I graph is a straight line.
- Many devices are **non-ohmic**. Their resistance changes with temperature or voltage. Examples include light bulbs and diodes.

Case Study: Nichrome Wire (Source Q65, Table 2)

A student measures the current through a nichrome wire at different voltages.

- At **2.00 V**: $I = 0.0140 \text{ A} \rightarrow R = 2.00/0.0140 = \mathbf{143 \, \Omega}$
- At **10.00 V**: $I = 0.0630 \text{ A} \rightarrow R = 10.00/0.0630 = \mathbf{159 \, \Omega}$
- As voltage and current increase, the wire heats up, and its resistance increases. The wire does not strictly obey Ohm's Law.

V-I Graph for Nichrome Wire



Practical Challenge: Power Loss in Transmission

The Problem

When current flows through a wire with resistance, some electrical energy is unintentionally converted into heat. This is called **Joule Heating** or **I^2R Loss**.

The Equation for Loss

$$P_{\text{loss}} = I^2R$$

- **I** is the current in the transmission line.
- **R** is the resistance of the line.

The Solution

To minimize energy loss, we must reduce the current (**I**).

- Remember that Power Delivered is **$P = I\Delta V$** .
- By dramatically **increasing the transmission voltage (ΔV)**, we can deliver the same amount of power with a much **smaller current (I)**.
- **Result:** Less current means significantly less I^2R power is lost as heat in the wires.



The Ultimate Cheat Sheet: Key Formulas & Definitions

Concept/Quantity		Formula(s)	Units
Core Concepts			
Current (I)		Flow of charge	Amperes (A)
Voltage (ΔV)		Potential difference	Volts (V)
Resistance (R)		Opposition to flow	Ohms (Ω)
Ohm's Law		$R = \Delta V / I$ $\Delta V = I * R$	
Electric Power (P)		$P = I * \Delta V$ $P = I^2 R$ $P = (\Delta V)^2 / R$	Watt (W)
Electric Energy (E)		$E = P * t$ $E = I^2 R t$ $E = ((\Delta V)^2 / R) * t$	Joule (J), kilowatt-hour (kWh)

Final Challenge: Test Your Mastery

*(Questions from Standardized Test Practice, Page 77)

1. A 100 W light bulb is connected to a **120 V line**. What is the **current** drawn by the the bulb? (Source Q1) (V)

- A. 0.83 A B. 1.2 A C. 120 A $\Rightarrow$ D. 12,000 A

(Answer: A. $I = P/V = 100W/120V$)

2. A 5.0Ω resistor is connected to a **9.0 V** battery. How much energy is converted in 7.5 min? (Source Q2) (I)

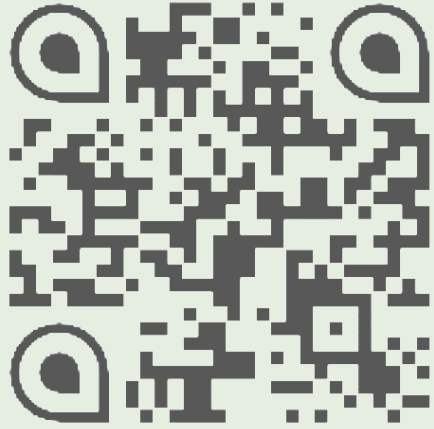
- A. 1.2×10^2 J B. 1.3×10^3 J C. 3.0×10^3 J D. 7.3×10^3 J

(Answer: D. $P = \frac{V^2}{R} = 81/5 = 16.2W$. $E = P \cdot t = 16.2W \cdot 450s$)

3. What is the effect on the current in a simple circuit if both the voltage and the resistance are reduced by half? (Source Q6) (W)

- A. Divided by 2 B. No change C. Multiplied by 2 D. Multiplied by 4

(Answer: B. $I = V/R$. New $I = (V/2)/(R/2) = V/R$)



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تكون هذه الملزمة قد حققت
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