

A Source Of E.m.f. $E = 15\text{ V}$ And Having Negligible Internal Resistance Is Connected To A Variable Resistance

A Source Of E.m.f. $E = 15\text{ V}$ And Having Negligible Internal Resistance Is Connected To A Variable Resistance is a fundamental setup in electrical circuits, often used to study the principles of Ohm's Law, power dissipation, and the behavior of electrical components under different load conditions. This configuration serves as an essential experiment in physics and electrical engineering, providing insights into how voltage, current, and resistance interact within a circuit. In this comprehensive article, we will explore the intricacies of such a setup, including the theoretical foundations, practical applications, and key concepts related to electromotive force (emf), internal resistance, variable resistors, and their significance in circuit analysis.

Understanding Electromotive Force (emf) and Internal Resistance

What is Electromotive Force (emf)?

Electromotive force (emf) is the voltage generated by a source such as a battery or a generator when no current is flowing. It represents the energy supplied per unit charge to move it around the circuit. For a source with emf $E = 15\text{ V}$, this indicates that each coulomb of charge gains 15 joules of energy as it passes through the source.

Internal Resistance of a Source

In real-world scenarios, electrical sources possess some internal resistance, which affects the overall performance of the circuit. Internal resistance is the resistance within the source itself, often due to the materials and design of the battery or generator.

- When a source has negligible internal resistance, it implies that the internal resistance is so small that it can be considered effectively zero.
- This idealization simplifies calculations and helps in understanding fundamental circuit behavior without the complicating effects of internal losses.

Connecting a Voltage Source to a Variable

Resistance

The Setup

In the typical experiment or application, a voltage source with emf $E = 15 \text{ V}$ and negligible internal resistance is connected to a variable resistor R . The variable resistor, often implemented as a rheostat or potentiometer, allows the resistance in the circuit to be adjusted continuously within a certain range.

Key components:

- Voltage source ($E = 15 \text{ V}$, negligible internal resistance)
- Variable resistor (R)
- Connecting wires and measuring instruments (ammeter, voltmeter)

Analyzing the Circuit Behavior

Ohm's Law and Its Application

Ohm's Law states that the current (I) flowing through a resistor (R) connected across a voltage source (E) is given by:

$$I = \frac{E}{R}$$

Since the emf E is constant at 15 V and the internal resistance is negligible, the current depends solely on the resistance R . As R varies:

- When R is small, the current I is large.
- When R increases, the current decreases proportionally.

Current-Resistance Relationship

The relationship between current and resistance in this ideal circuit is straightforward:

$$I = \frac{15 \text{ V}}{R}$$

This inverse relationship implies that:

- Reducing the resistance increases the current.
- Increasing the resistance decreases the current.

Power Dissipation in the Resistor

The power dissipated as heat in the resistor R can be calculated using:

$$P = I^2 R = \frac{E^2}{R}$$

- As resistance R decreases, power dissipation increases.
- When R is very high, power dissipation diminishes.

Practical Applications and Significance

Studying Resistance and Current

This setup is fundamental in understanding how varying resistance impacts current flow in a circuit. It forms the basis for:

- Designing electrical circuits with desired current levels.
- Analyzing power consumption and heat generation.

Calibration and Testing of Electrical Components

Using a variable resistor with a known emf source allows engineers and physicists to:

- Calibrate instruments.
- Test the behavior of different resistive materials.
- Study the limits of current and voltage ratings.

Educational Demonstrations

This simple yet powerful setup is extensively used in educational environments to demonstrate:

- Ohm's Law.
- The relationship between emf, resistance, and current.
- The concept of internal resistance and its negligible approximation.

Implications of Negligible Internal Resistance

Ideal vs. Real-World Scenarios

While the assumption of negligible internal resistance simplifies analysis, real sources do have internal resistance, affecting:

- The actual voltage across the external resistor.
- The current flowing in the circuit.
- Power losses within the source.

Advantages of the Assumption

Assuming negligible internal resistance:

- Simplifies calculations.
- Allows focus on the resistance of external components.
- Provides a theoretical upper limit for circuit performance.

Limitations and Real-World Considerations

In real circuits, internal resistance impacts the efficiency and voltage regulation. It is important to:

- Measure internal resistance for accurate circuit analysis.
- Use ideal sources only as approximations.

Experimentation and Measurement Techniques

Measuring Current and Voltage

To analyze the circuit:

- Use an ammeter in series with the resistor to measure current.
- Use a voltmeter across the resistor to measure the voltage drop.

Adjusting Resistance

By varying the resistor R :

- Record corresponding current I .
- Calculate the power dissipated.
- Plot graphs of I vs. R or P vs. R for visual analysis.

Data Interpretation

From collected data, students and engineers can:

- Verify Ohm's Law.
- Determine the internal resistance if it's not negligible.
- Understand the maximum current and power limits.

Advanced Topics and Extensions

Internal Resistance in Practical Sources

Real batteries and power supplies exhibit internal resistance, which causes voltage drops and reduces the effective emf delivered to the external circuit. The actual voltage across the resistor becomes:

$$V = E - I r_{\text{int}}$$

where (r_{int}) is the internal resistance.

Effect on Circuit Performance

Internal resistance influences:

- The maximum current the source can supply.
- The efficiency of power transfer.
- The thermal management of the source.

Design Considerations

Engineers must optimize:

- The internal resistance of power sources.
- The resistance in external circuits.
- The overall system efficiency.

Summary and Key Takeaways

To summarize:

- Connecting a 15 V emf source with negligible internal resistance to a variable resistor

demonstrates fundamental electrical principles.

- The circuit's behavior is governed by Ohm's Law, with current inversely proportional to resistance.
- Power dissipation varies with resistance, influencing heat generation.
- Such setups are invaluable educational tools and practical test circuits.
- The assumption of negligible internal resistance simplifies analysis but must be considered when designing real-world systems.

Key points:

- Electromotive force (E): 15 V
- Internal resistance: Negligible (ideal source)
- Resistance (R): Adjustable
- Current (I): $\left(\frac{E}{R} \right)$
- Power dissipation: $\left(\frac{E^2}{R} \right)$

Conclusion

Understanding the dynamics of a source with emf $E = 15\text{ V}$ and negligible internal resistance connected to a variable resistor forms the foundation of circuit analysis in physics and electrical engineering. It highlights the essential relationships between voltage, current, and resistance, fostering deeper comprehension of electrical principles. Whether used in educational demonstrations, circuit design, or advanced research, this setup offers an accessible yet powerful means to explore the fundamental laws governing electrical circuits.

Optimized for SEO Keywords:

- Source of emf 15 V
- Negligible internal resistance
- Variable resistor circuit
- Ohm's Law applications
- Electrical circuit analysis
- Power dissipation in resistors
- Circuit with variable resistance
- Electromotive force explained
- Internal resistance effects
- Electrical measurement techniques

Frequently Asked Questions

What is the significance of a source of emf with negligible internal resistance when connected to a

variable resistance?

It ensures that the entire emf is available across the external resistance without any voltage drop inside the source, allowing accurate study of the circuit's behavior with varying resistance.

How does varying the resistance affect the current in a circuit with a 15 V emf source and negligible internal resistance?

The current varies inversely with the resistance according to Ohm's Law ($I = V/R$); increasing resistance decreases current, and vice versa.

What is the relationship between emf, resistance, and current in this setup?

Since internal resistance is negligible, emf (E) equals the voltage across the external resistance, and current (I) is given by $I = E/R$.

Why is it important to consider the internal resistance of a source, and what happens when it's negligible?

Internal resistance causes voltage drops within the source, reducing the voltage across external components; when negligible, the emf is effectively the voltage across the external circuit only.

How can one experimentally determine the resistance when connected to this emf source?

By measuring the current for different resistance values and applying Ohm's Law ($R = E/I$), since the emf is known to be 15 V.

What are the practical applications of using a source with negligible internal resistance?

It is ideal for precise measurements and testing circuits where voltage drops inside the source must be minimized for accuracy.

What effect does increasing resistance have on power dissipation in this circuit?

Power dissipated is $P = I^2 R$; as resistance increases, power dissipation in the external resistor increases, while the current decreases.

Can this setup be used to determine internal resistance of a real source? Why or why not?

No, because the internal resistance is considered negligible; to find internal resistance, a source with known emf and measurable internal voltage drops is required.

What safety precautions should be taken when varying resistance in a circuit connected to this emf source?

Ensure the resistance values are within safe limits to prevent overheating, use proper insulation, and avoid short circuits to protect the source and components.

Additional Resources

A Source Of E.M.F. $E = 15\text{ V}$ And Having Negligible Internal Resistance Is Connected To A Variable Resistance

Introduction

In the realm of electrical engineering and physics, understanding the behavior of sources of electromotive force (E.M.F.) and their interaction with external resistances is fundamental. When a source of E.M.F. with an idealized characteristic—specifically, a voltage of 15 volts and negligible internal resistance—is connected to a variable resistor, the resulting circuit behavior reveals important insights into circuit analysis, power transfer, and efficiency. This investigation delves into the theoretical and practical aspects of such a setup, exploring how the circuit responds to changes in the external resistance and the implications for real-world applications.

The Nature of the Source: An Ideal E.M.F. with Zero Internal Resistance

Characteristics and Assumptions

An ideal source of E.M.F., with a specified 15 V and negligible internal resistance (often considered zero for theoretical models), exhibits specific behaviors:

- **Constant Voltage Output:** The voltage across the terminals remains fixed at 15 V regardless of the current drawn.
- **No Internal Voltage Drop:** Since internal resistance is negligible, the source does not experience voltage drops internally, ensuring maximum potential difference is delivered to the external circuit.
- **Unlimited Current Capability:** In theory, if connected directly across a short circuit, the source could supply an arbitrarily large current, which is physically impossible but useful for idealized analysis.

Practical Considerations

While ideal sources serve as a baseline model, real-world sources possess internal resistances that limit current and affect voltage delivery. Nonetheless, the ideal case simplifies the analysis, allowing focus on the effects of the external resistance.

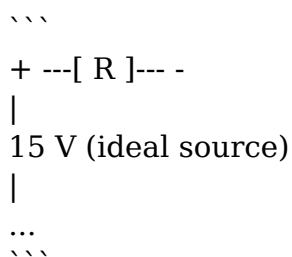
Connecting the Source to a Variable Resistance

Circuit Configuration

Consider the circuit where the 15 V ideal source is connected across a variable resistor, (R) . The circuit diagram simplifies to:

- Power Source: 15 V, negligible internal resistance.
- External Resistance: (R) , adjustable from near zero to very large values.

The circuit can be represented as:



Since the internal resistance is negligible, the entire voltage appears across (R) .

Basic Circuit Analysis

Applying Ohm's Law:

$$V = I \times R$$

Given the source voltage $(E = 15\text{ V})$:

$$I = \frac{E}{R}$$

This simple relation indicates that the current through the circuit varies inversely with the external resistance.

Behavior of the Circuit with Varying Resistance

Resistance at Extreme Values

- When $(R \rightarrow 0)$:

The external resistance approaches zero, simulating a short circuit.

Theoretical current:

$$I \rightarrow \infty$$

However, in practice, the current is limited by the internal resistance of the source (which is considered zero in the ideal case) and the physical constraints of the circuit components.

- When $(R \rightarrow \infty)$:

The circuit becomes open, and the current tends to zero.

Voltage across (R) :

$$V_R = E = 15\text{V}$$

No current flows.

Intermediate Resistance Values

For any finite (R) :

$$I = \frac{15\text{V}}{R}$$

The power dissipated in (R) :

$$P = I^2 R = \left(\frac{15}{R}\right)^2 R = \frac{225}{R}$$

This relation indicates that power peaks at a specific resistance value and diminishes at both very low and very high resistance values.

Power Transfer and Maximum Power Theorem

Power Dissipation in External Resistance

The power transferred to the external resistance:

$$P = I^2 R = \left(\frac{E}{R}\right)^2 R = \frac{E^2}{R}$$

Graphically, as (R) varies:

- Power decreases as (R) increases (since $P \propto 1/R$)
- Power increases as (R) decreases toward zero, but physically, infinite current cannot be sustained.

Condition for Maximum Power

According to the maximum power transfer theorem, maximum power is delivered to the load when:

$$R = R_{\text{source}}$$

In this ideal case, since the internal resistance is negligible ($R_{\text{internal}} \approx 0$), the maximum power transfer theoretically occurs at $(R \rightarrow 0)$. Practically, the maximum power is limited by the source's internal resistance and the circuit's physical constraints.

Implications for Circuit Design and Practical Applications

Real-World Considerations

While the idealized model provides insights, real power sources have internal resistance, which impacts current and voltage behavior. For example:

- Battery or generator with internal resistance:
The total voltage across the external resistor is reduced due to internal voltage drops.
- Voltage regulation:
Maintaining a constant voltage across varying loads requires sources with controlled internal resistance or feedback mechanisms.

Practical Applications

Understanding the behavior of a source with negligible internal resistance connected to variable resistance is critical in:

- Designing power supplies for maximum efficiency.
- Analyzing load characteristics in circuits.
- Developing adjustable power sources in laboratory settings.
- Studying the limits of idealized models to inform real-world system design.

Limitations of the Idealized Model

Despite its usefulness, the model's assumptions can lead to misconceptions:

- Actual sources cannot sustain infinite current; internal resistance, temperature effects, and component ratings impose limits.

- Overlooking internal resistance may overestimate circuit performance.
- Safety considerations in practical circuits prevent short circuits, which are theoretically represented by $(R \rightarrow 0)$.

Conclusion

Connecting a source of E.M.F. $E = 15\text{ V}$ and having negligible internal resistance to a variable resistance illustrates fundamental principles of circuit behavior, power transfer, and the influence of load resistance on current and voltage. In the idealized scenario, the circuit demonstrates that current varies inversely with resistance, with maximum power transfer approaching the short-circuit condition. However, real-world applications necessitate consideration of internal resistances and safety constraints.

This analysis underscores the importance of understanding theoretical models as foundational tools, which guide the design and optimization of practical electrical systems. As technology advances, the pursuit of near-ideal sources continues, driven by the need for efficient, reliable power delivery in increasingly sophisticated electronic devices.

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