Experiment 2: Verification of Superposition Theorem

1. Introduction

The Superposition Theorem is a fundamental principle used to analyze complex electrical circuits that contain multiple energy sources. It simplifies the analysis by allowing us to consider the effect of each source independently.

2. Objective

To verify the Superposition Theorem for a linear DC circuit with multiple independent voltage sources.

3. Apparatus Required

S.No	Apparatus	Quantity
1.	Breadboard	1
2.	DC Power Supplies (e.g., 12V and 5V)	2
3.	Resistors (e.g., R_1, R_2, R_3 of known values)	3
4.	Digital Multimeter (DMM) for measuring current	1
5.	Connecting Wires	As required

4. Theory

Statement: The Superposition Theorem states that in any **linear, bilateral network** containing two or more independent sources (voltage or current), the response (current through or voltage across) in any element is the **algebraic sum** of the responses produced by each source acting alone, while all other sources are replaced by their internal resistances.

Key Conditions:

1. **Linear Circuit:** The theorem only applies to circuits composed of linear elements (resistors, capacitors, inductors) where the relationship between voltage and current is linear (Ohm's Law).
2. **Deactivating Sources:**
    - **Voltage Source:** Replaced by a **Short Circuit** (0V). Ideally, a plain wire.
    - **Current Source:** Replaced by an **Open Circuit** (0A). Ideally, a break in the wire.

Mathematical Representation: If I is the total current in a branch due to sources V_1 and V_2:

$$I = I' + I''$$

Where:

- I' is the current due to source V_1 alone (with V_2 shorted).
- I'' is the current due to source V_2 alone (with V_1 shorted).

Limitations:

- It does **not** apply to non-linear circuits (containing diodes, transistors).
- It cannot be used to calculate **Power** directly because power is a non-linear quantity ($P = I^2R$).

5. Circuit Diagram

Standard T-Network Configuration:

- **Resistor R_1:** Connected to Source V_1 (e.g., 12V).
- **Resistor R_3:** Connected to Source V_2 (e.g., 5V).
- **Resistor R_2:** The central branch connected to Ground.
- **Node A:** The junction point connecting R_1, R_2, R_3.

The goal is to find the current flowing through the central resistor R_2 (let's call it I_{R2}).

6. Procedure

Step 1: Both Sources Active

1. Connect the circuit with both voltage sources V_1 (e.g., 12V) and V_2 (e.g., 5V) present.
2. Connect an Ammeter in series with the central resistor R_2.
3. Measure the total current flowing through R_2.
4. Record this value as I_{total}.

Step 2: Source V_1 Active Only

1. **Turn off** or disconnect source V_2.
2. **Short Circuit** the terminals where V_2 was connected. (Replace the battery with a connecting wire).
3. Keep source V_1 active.
4. Measure the current flowing through R_2 with the ammeter.
5. Record this value as I' (Current due to V_1 alone).

Step 3: Source V_2 Active Only

1. **Reconnect** source V_2.

2. **Turn off** or disconnect source V_1.
3. **Short Circuit** the terminals where V_1 was connected.
4. Keep source V_2 active.
5. Measure the current flowing through R_2 with the ammeter.
6. Record this value as I'' (Current due to V_2 alone).

Step 4: Verification

1. Algebraically add the individual currents: $I_{calc} = I' + I''$.
    - *Note: Pay attention to current direction! If I' flows downward and I'' flows upward, you subtract them.*
2. Compare I_{calc} with the measured I_{total} from Step 1.
3. If $I_{total} \approx I' + I''$, the theorem is verified.

7. Observation Table

Case	Active Source(s)	Voltage V_1 (V)	Voltage V_2 (V)	Current through R_2 (mA)
1	Both V_1 & V_2	12V	5V	$I_{total} = $ ...
2	Only V_1	12V	0V (Short)	$I' = $ ...
3	Only V_2	0V (Short)	5V	$I'' = $ ...

Verification Result:

$$I_{total} \text{ (Measured)} = \_\_\_\_\_ \text{ mA}$$

$$I' + I'' \text{ (Calculated)} = \_\_\_\_\_ \text{ mA}$$

Error = ...

8. Precautions

1. **Shorting Sources:** When deactivating a voltage source, ensure you short the terminals on the circuit board, not the power supply itself (which would blow the supply fuse). Disconnect the supply first, then bridge the gap on the breadboard.
2. **Polarity:** Be very careful with the direction of current. If the multimeter shows a negative sign, record it as negative. Superposition is an **algebraic** sum.
3. **Linearity:** Ensure the resistors are not overheating, as temperature changes can cause non-linear behavior.

9. Conclusion

The current measured when both sources were active (I_{total}) was found to be equal to the algebraic sum of the currents measured when each source acted independently ($I' + I''$). Thus, the Superposition Theorem is verified.