Resistance in a Series Circuit

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1. Learning Outcomes

Learners normally learn, in connection with Ohm's law, the relationship between electric current, potential difference, and resistance out of their textbooks. Then they work through some problem-solving exercises using Ohm's law formula, based on which they calculate resistance value in a series circuit.

As opposed to such a conventional learning method, this experiment guide is intended for learners to understand the relationship between resistance value in a series circuit and Ohm's law formula through their experiments.

As for the learning outcomes, learners will recognize 1) the amount of electric current flowing in any position of a series circuit is consistent, and 2) the whole potential difference in a series circuit is equal to the sum of potential difference across each component in the circuit. Consequently, learners will understand that the whole resistance value in a series circuit is equal to the sum of a resistance value of each component with the help of Ohm's law formula.

2. Introduction of Equipment for Experiments

1. Miniature DC ammeter and Miniature DC voltmeter

DC ammeter and DC voltmeter are required for this experiment. Caution is needed when connecting conventional DC ammeter or DC voltmeter to electric circuit because these types of meters will be damaged unless connected to a terminal with proper measurement range. Multimeter can be misleading equipment for learners, too, because they tend to waste much time in unrelated measurement due to the multi functions. In the following experiment, user friendly miniature digital DC ammeter and digital DC voltmeter with a single function will be used so that learners can do various experiment in a short time.

A05-7060 Miniature DC Ammeter

- ●Measurement range: ±3A
- ●Automatic range change: 1mA (0~±500mA)
  0.01A (0.51~±3.0A)
- ●Size: 53 × 21 × 15mm, Whole length: 280mm
- ●Battery: CR1220 x 1pc

A05-7065 Miniature DC Voltmeter

- ●Measurement range: ±25V
- ●Automatic range change: 0.01V (0~±5.00V)
  0.1V (±5.1V~±25.0V)
- ●Size (body): 53 × 21 × 15mm, Whole length: ca. 280mm
- ●Battery: CR1220 x 1p

With these miniature meters, learners are no longer required to spend their time for the troublesome measurement range selection as happens with multimeters. These meters are suitable for learners experiments due to the following functions such as automatic measurement range change and built-in protection circuit for overload prevention. Furthermore, it is possible for learners to view this meter as a part of electric circuit because they are small enough when compared with conventional ones.

2. Resistors

Resistors for educational purpose differ from the ones available in the general market in the following: 1) the former are arranged for learners' experiments in school while the latter are designed as parts for appliances (difference in intended use) and 2) the former are produced in low quantity while the latter are mass- produced (difference in production volume). Resistors used in this experiment guide are those specially designed for students by Narika Corporation. Instructors can secure the safety of learners during their experiment. Learners can carry their experiments on this topic without worry.

Name of product: Cement resistor for students' experiments				
Cat. No. B10-5752-01	Cat. No. B10-5752-02	Cat. No. B10-5752-03	Cat. No. B10-5752-04	Cat. No. B10-5752-05
				
●Spec.: 10Ω 5W ●Letter color: Red	●Spec.: 20Ω 5W ●Letter color: Orange	●Spec.: 30Ω 5W ●Letter color: Green	●Spec.: 40Ω 5W ●Letter color: Blue	●Spec.: 50Ω 5W ●Letter color: Purple
●Size: 80 × 50 × 25mm ●Protective cover (built-in protective plastic cover for students' safety)				

DC power supply equipment or dry cell(s) batteries are generally used as the power supply for students' electricity experiments, in which case large electric current (over 3 amperages) can flow. Furthermore, some types of power supply equipment can supply a maximum of 5 amperages. Therefore, students sometimes face the risk of getting burnt when touching a resistor heated by electric current. This is why the cement resistor for students' experiments has a built-in protective cover. Students often select incorrect cement resistor in their experiments because each resister has a similar appearance. To avoid this, color-coded resistance value (see specification) for each type of the cement resistor is printed on the protective cover. For example, specification of "10 ohms" is printed in red and "20 ohms" in orange.

3. Other items for students' experiments

A knife switch and a connecting terminal base are strongly recommended to use to carry students' experiment with no difficulty. These items will make the wiring much easier and then, help students smoothly assemble their electric circuits exactly according to the electrical diagram.

B10-6254-01 Knife switch	B10-6255-10 Connecting terminal base
	
●Switch: Single ●Size: ca. 80 × 50 × 5mm	●Size: ca. 50 × 50 × 26mm

3. Resistance in a series circuit

1. Purpose of this experiment:

It is the purpose of this section to help learners induce the relational expression (R = R1 + R2 +….+ Rn) of resistance values of resistances connected in series according to the measurement results of the electric current and the potential difference in the series circuit. Learners should better derive and retain the equation through hands-on experiments rather than learning from textbook.

2. What to prepare:

・A05-7060 Miniature DC ammeter CT-A: 1 ~ 3pcs
・A05-7065 Miniature DC voltmeter CT-V: 1 ~ 3pcs
・B10-6254-1 Knife switch (hereinafter "Switch"): 1pcs
・P70-0720-03 AA dry cell batteries: 1pcs
・P70-0342 Battery holder AA: 4pcs
・B10-6503 Lead wire with clips (Red & Black): 2pairs
・B10-5752-01 Cement resistor for students' experiments (10Ω): 2pcs

3. Experiment

1. Current flowing in a series circuit

Measure electric current flowing in a series circuit with two resistances using ammeters and analyze the measurement values.

1) Assemble a series circuit with three ammeters, a dry cell battery, two resistors (10Ω) and a switch (see Fig. 1).

2) Measure the electric current flowing through each ammeter as shown in Fig. 1.

3) Fill these measurement values in Table 1.

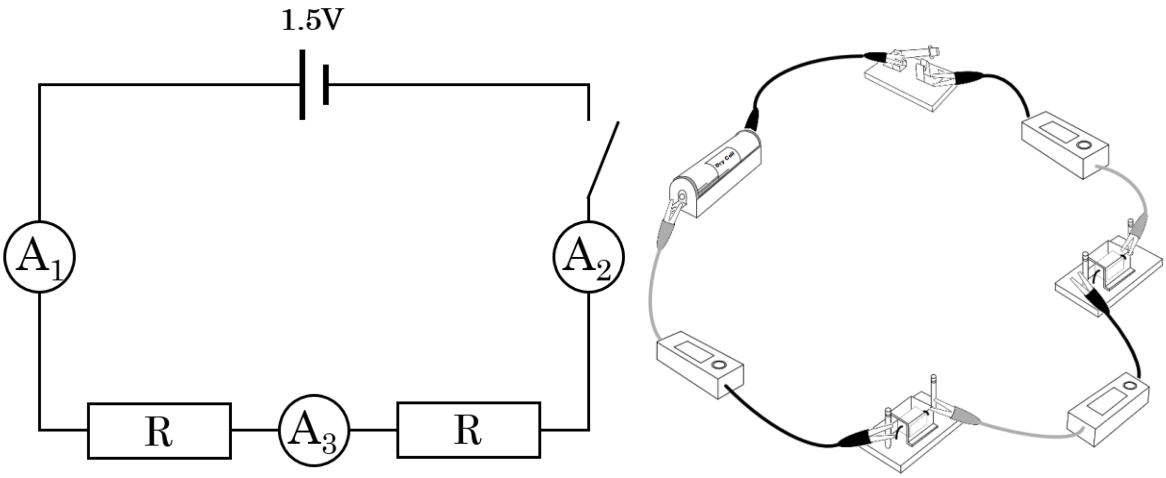

Fig. 1 Resistors and Ammeters connected in a series circuit

Table 1. Amperes in the series circuit (Experiment 1)

A_1	A_2	A_3
78 mA	77 mA	77 mA

4) Summarize the findings from the electric current flowing in the series circuit with two resistors according to the experiment results (see Table 1).

The amount of electric current flowing in each of two resistors connected in series is consistent because values of amperage measured at each of the three points (A_1, A_2, A_3) are mostly the same as shown in Table 1 (A_1=A_2=A_3).

2. Potential difference across two points in a series circuit

Measure the potential difference across two resistors connected in series using voltmeters and analyze the measurement values.

1) Assemble a series circuit with three voltmeters, a dry cell battery, two resistors (10Ω) and a

switch (see Fig. 2).

2) Measure the potential difference at each of voltmeters as shown in Fig. 2.

3) Fill these measurement values in Table 2.

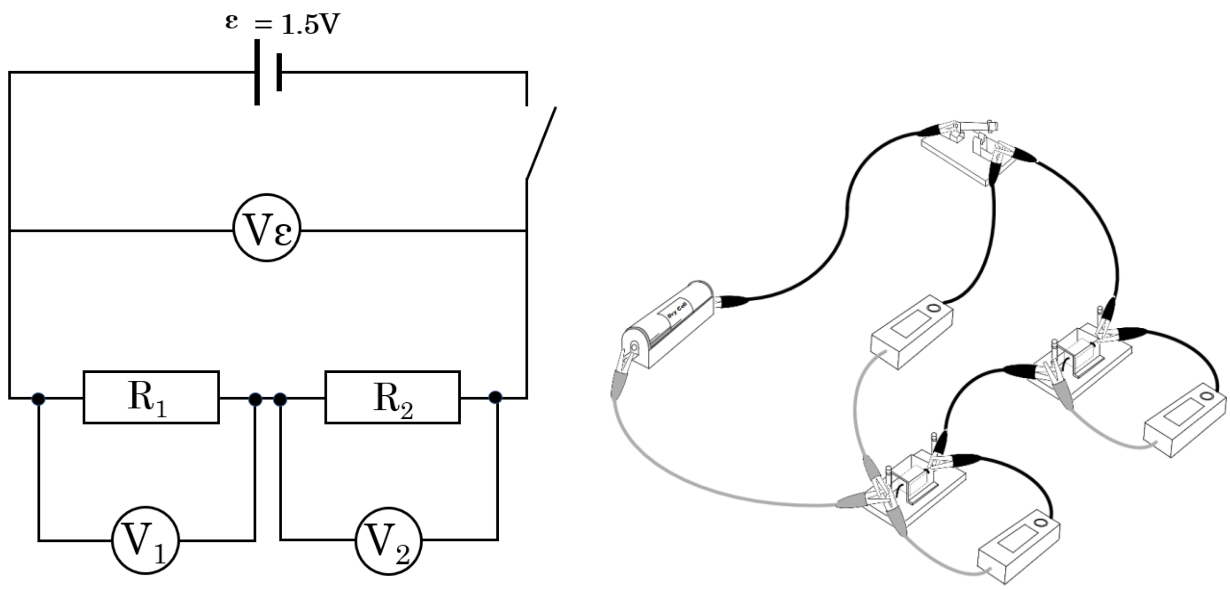

Fig. 2 Resistors and Voltmeters connected in a series circuit

Table 2. Voltages in the series circuit (Experiment 2)

V_ε	V_1	V_2
1.6 V	0.8 V	0.8 V

4) Summarize the findings from the potential difference across two resistors connected in the series circuit according to the experiment results (see Table 2).

The sum of voltage across each of the two resistors connected in series is equal to the voltage of the whole circuit according to the measurement result as shown in Table 2 ($V_\varepsilon = V_1 + V_2$).

Furthermore, if taking power source voltage ε into consideration, the relational expression will be $\varepsilon = V_\varepsilon = V_1 + V_2$.

3. Calculate each resistance value from the measurement result shown in Table 1 and 2.

1) Calculate resistance value R (Ω) from the measurement result shown in Table 1 and 2 using the equation ***V = IR*** or ***R = V/I*** of Ohm's law. Then, fill the calculated R (Ω) in Table 3. Note that the unit for ampere has to be changed from mA to A.

Table 3. Calculated resistances for the result

A from Table 1 (A)	V from Table 2 (V)	Calculated Resistance (Ω)
0.078	V_ε = 1.6	20.5
	V_1 = 0.8	10.3
	V_2 = 0.8	10.3

2) Formulate the relationship between each of the calculated resistances shown in Table 3 and the total value (see Fig. 3 and Fig. 4).

$R = R_1 + R_2$

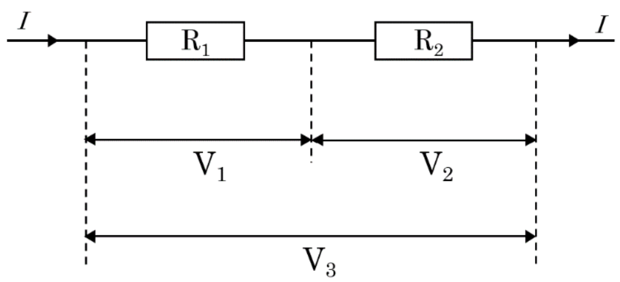

Fig. 3 Resistances in a series circuit

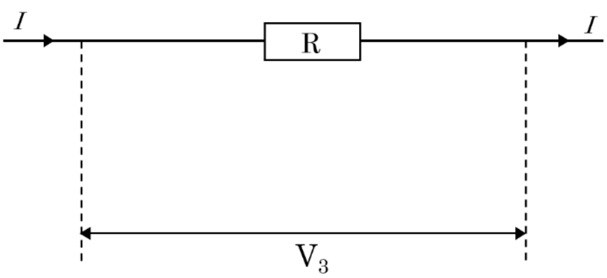

Fig. 4 Resistance in a simple circuit

6. Description

Learners normally learn, in connection with Ohm's law, the relationship between electric current, potential difference and resistance out of their textbooks. They then work through some problem-solving exercises using Ohm's law formula, based on which they calculate resistance value in a series circuit.

Total resistance value in series is expressed as the mathematical formula: $R = R_1 + R_2 + \dots + R_n$, which learners are normally taught from their textbooks. They learn the relational expression of values of resistances connected in series based on the Ohm's law equation, the relationship between voltage, ampere, and resistance without conducting experiments. In other words, learners' effort is only spent to learn and memorize the mathematically expressed formula.

The experiment guide is intended to be a departure from a science lesson focused on rote memory (blackboard centered science lesson) to an experiment-oriented science lesson. Therefore, if learners realize the relationship between voltage, electric current, and resistance through the experiments, it can be taken as a proof of achievement of original intention of this guide.

Through the experiments, the learners will realize that amount of electric current flowing in a series circuit is almost consistent as shown in Table 1 and voltage of whole circuit is equal to the sum of voltages across each of the resistors as shown in Table 2 (ε =V ε =V1 + V2). Consequently, they can expand the formula as follows in combination with the Ohm's law.

$$V\varepsilon = V_1 + V_2$$

$$V\varepsilon = IR_1 + IR_2 = I(R_1 + R_2)$$

$$\therefore \quad V\varepsilon / I = R_1 + R_2$$

$$\therefore \quad R = R_1 + R_2 + ... + Rn$$

On the other hand, this guide is not intended to take resistance value of "10Ω" marked on the resistor as given, but to measure actual values of voltage and electric current to calculate resistant values (Experiment 1 and 2), by which learners will induce the mathematical formula: $R = R_1 + R_2$ after confirming that calculated resistance value is almost equal to the rated value (10Ω) marked on the resistor.

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