Resistance in a Parallel Circuit

NaRiKa Corporation

1. Learning Outcomes

Learners normally learn, in connection with Ohm's law, the relationship between resistance, voltage, and current out of their textbook. They, then, work through some problem-solving exercise using Ohm's law formula, based on which they calculate resistance value in a parallel circuit.

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

As for the learning outcomes, learners will recognize 1) the whole electric current flowing in a parallel circuit is equal to the sum of electric current flowing through each component (branch), and 2) voltage value across a component of each branch of the parallel circuit is equal to each other. Consequently, learners will understand this through their experiments.

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. In order 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 parallel circuit

1. Purpose of this experiment:

It is the purpose of this section to help learners induce the relational expression ($1/R = 1/R_1 + 1/R_2 +\cdots.+ 1/R_n$) of resistance values according to the measurement results of the electric current and the potential difference in the parallel 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
- B10-6254-01 Knife switch (hereinafter "Switch"): 1pc
- P70-0720-03 AA dry cell batteries: 1pc
- P70-0342 Battery holder AA: 4pcs
- B10-6503 Lead wire with clips (Rad & Black): 2pairs
- B10-5752-01 Cement resistor for students' experiments (10Ω): 2pcs

3. Experiment

1. Current flowing in a parallel circuit

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

1) Assemble a parallel 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.

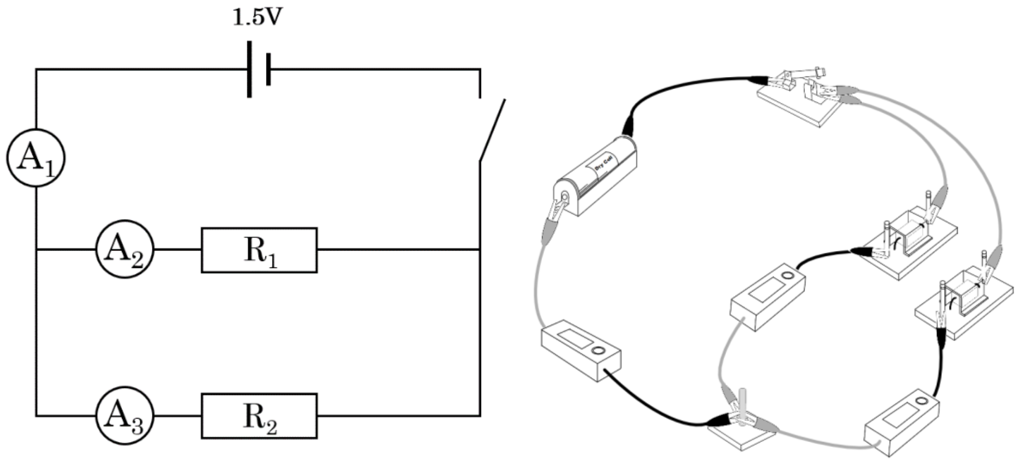

Fig. 1 Resistors and Ammeters connected in a parallel circuit

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

A_1	A_2	A_3
245 mA	123 mA	120 mA

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

The amount of electric current flowing from the dry cell battery measured at ammeter (A_1) is equal to the sum of each amount of electric current flowing through each resistor (A_2 and A_3), which can be expressed as $A_1 = A_2 + A_3$.

2. Potential difference across in a parallel circuit

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

1) Assemble a parallel 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 shown in Fig. 2.

3) Fill these measurement values in Table 2.

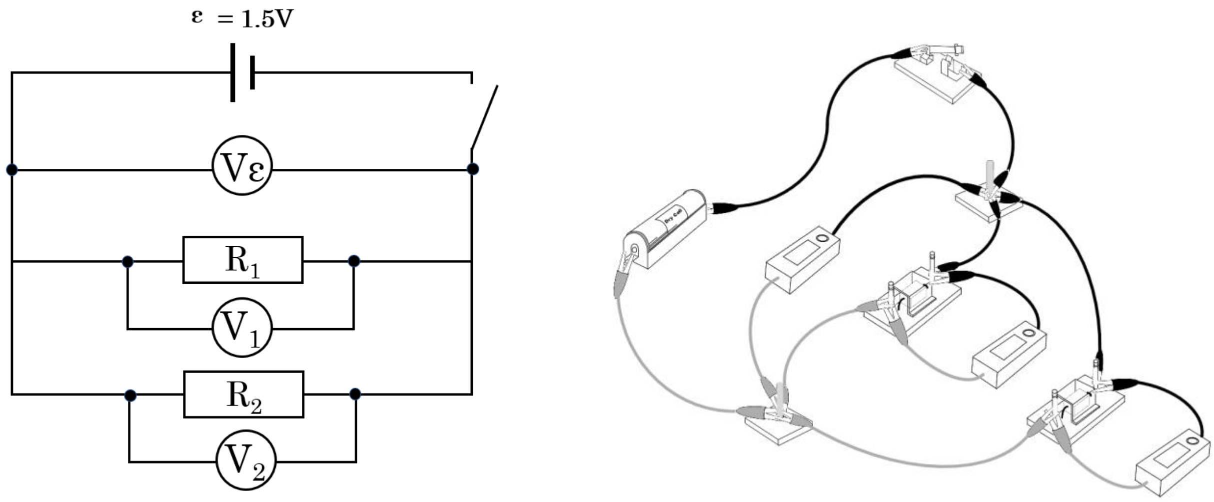

Fig. 2 Resistors and Voltmeters in a parallel circuit

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

$V\varepsilon$	V_1	V_2
1.5 V	1.4 V	1.4 V

4) Summarize the findings of the potential difference across each of the two resistors in the parallel circuit according to the experiment results (see Table 2).

Value of $V\varepsilon$ shown in Table 2 is equal to the rated voltage of the dry cell battery (1.5V), and is almost the same as either value of V_1 or V_2. From this we can formulate $V\varepsilon = V_1 = V_2$.

3. Calculate each resistance value of resistors (R_1, R_2) 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 according to 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)
A_1= 0.245	V_ε = 1.5	R = 6.1
A_2= 0.123	V_1 = 1.4	R_1= 11.4
A_3= 0.120	V_2 = 1.4	R_2= 11.7

2) Explain that the combined resistance for the whole circuit is given by $1/R = 1/R_1 + 1/R_2$ based on the results shown in Table 1, 2 and 3.

Each of the calculated resistance values can be obtained using Ohm's law equation (R = V/I, or I = V/R after transformation). On the other hand, whole electric current in the circuit (I) can be expressed as $I = I_1 + I_2$ ($A_1 = A_2 + A_3$) according to Table 1. If two equations of I = V/R and $I = I_1 + I_2$ are combined together, $V/R = V_1/R_1 + V_2/R_2$ is obtained, which finally can be transformed to $1/R = 1/R_1 + 1/R_2$, according to Table 2, representing the result of Table 3.

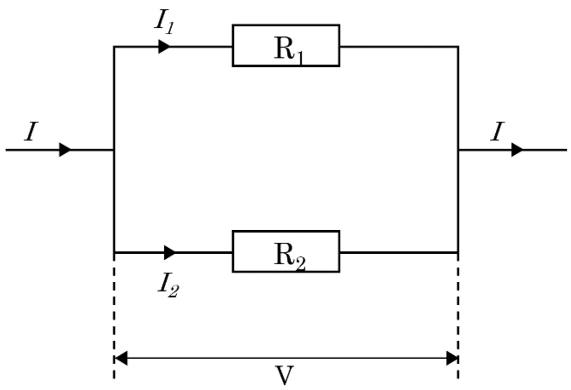

Fig. 3 Resistances in a parallel circuit

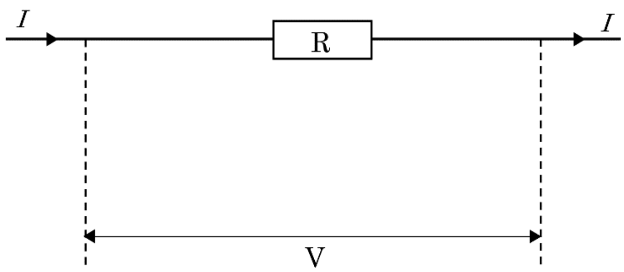

Fig. 4 Resistance in a simple circuit

6. Description

Resistance value of whole parallel circuit can be expressed as $1/R = 1/R_1 + 1/R_2 + \ldots + 1/R_n$, which learners normally learn from textbooks by substituting the relationship between voltage and electric current into Ohm's law formula 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 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 for achievement of original intention of this guide.

Amount of electric current flowing whole parallel circuit (from the cell) is equal to the sum of each amount of electric current flowing through each branch, which can be formulated as $A_1 = A_2 + A_3$, according to Experiment 1 (Table 1). Potential difference across resistors in each branch of a parallel circuit and the one across the entire circuit are equal to one another, according to Experiment 2 (Table 2), which can be formulated as $V_\varepsilon = V_1 = V_2$. Then, based on Experiment 3 (Table 3), learners try to calculate the resistance values using Ohm's law formula (R = V/I).

If the learners notice that R = V/I can be transformed to I = V/R, they will easily induce the equation of $1/R = 1/R_1 + 1/R_2$.

On the other hand, in Experiment 1 and 2, learners calculate the resistance value based on the measured voltage and electric current without using a rated resistance value (10Ω) marked on the cement resistor. However, this will be a good opportunity for learners to induce the equation (1/R = 1/R1 + 1/R2) because they are highly likely to compare the marked value with their calculated resistance value.

In addition, learners will be able to recognize that measured value obtained through experiment contains some errors as there is some difference between the calculated resistance value and rated resistance value on the cement resistor.

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