Ohm's Law Experiments

NaRiKa Corporation

1. Learning Outcomes

It is the purpose of this experiment guide to help learners study Ohm's law through their experiments. As of the learning outcomes, they will induce the Ohm's law out by themselves through the experiments in which they draw graphs of the relationship between voltage, current, and resistance.

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
●Automatically switchable display: 1mA (0~±500mA)
                              0.01A (~±3.0A)
●Size: 53 × 21 × 15mm、Whole length: ca 280mm
●Battery: CR1220 x 1pc

A05-7065 Miniature DC Voltmeter
●Measurement range: ±25V
●Automatically switchable display: 0.01V (0~±5.00V)
                              0.1V (±5.1V~±25.0V)
●Size (body): 53 × 21 × 15mm, Whole length: ca280mm
●Battery: CR1220 x 1pc

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 components 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. Experiment of Ohm's Law

Many researchers started research activities on electricity derived from the "Volta cell", the world first electric battery, invented by an Italian physicist, Alessandro Giuseppe Antonio Anastasio Volta. A German physicist, Georg Ohm, was one of those researchers. In the course of his study of the "Volta cell", he discovered the proportional relationship between potential difference across two points in a conductive metal wire and the electric current flowing through the wire. He released the "Ohm's law" in 1827.

1. Purpose of this experiment:

It is the purpose of this experiment to help learners induce the Ohm's law by themselves. They will try to measure voltage and ampere of electricity flowing through a simple electric circuit assembled with a resistor, a switch and a dry cell battery. They will also try to graph their data. Finally, they will induce the Ohm's law based on the relationship between voltage and amperage they measure.

2. What to prepare:

・A05-7060 Miniature DC ammeter CT-A: 1 pc
・A05-7065 Miniature DC voltmeter CT-V: 1 pc
・B10-6254-1 Knife switch (hereinafter switch): 1 pc
・B10-6413 Miniature bulb base: 1 pc
・P70-0366-11 Miniature bulb (3.8V, 0.3A): 1 pc
・P70-0720-03 AA dry cell batteries: 4 pcs
・P70-0342 Dry cell battery holder AA: 4pcs
・B10-6503 Lead wire with clips (Rad & Black): 2 pairs

· B10-5752-01 Cement resistor for students' experiments (10Ω): 1 pc
· B10-5752-02 Cement resistor for students' experiments (20Ω): 1 pc
· B10-5752-03 Cement resistor for students' experiments (30Ω): 1 pc

3. Experiment

1. Measuring voltage and ampere of electricity flowing through an electric circuit (1)

1) Assemble a simple circuit as shown in Fig. 1 below with a resistor (10Ω), a dry cell battery, a switch, an ammeter, and a voltmeter.
2) Close the switch to measure the voltage and ampere, and then fill the measurement values in Table 1.
3) Open the switch and add another dry cell to assemble the circuit with two dry cell batterie.
4) Close the switch again to measure the voltage and ampere, and then fill the measurement values in Table 1.
5) Open the switch again to assemble the circuit by increasing the number of dry cell batteries up to four (4). Measure the voltage and ampere in each case of three and four dry cell batteries, and then fill the measurement values in Table 1 (see Fig. 2 and Fig. 3).
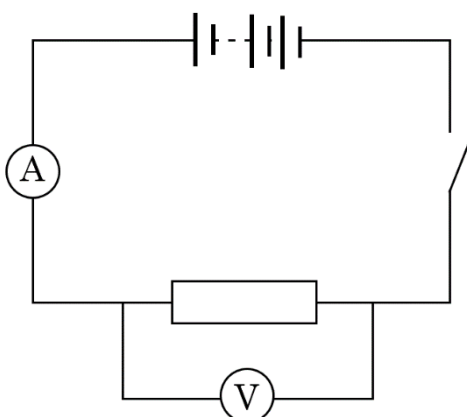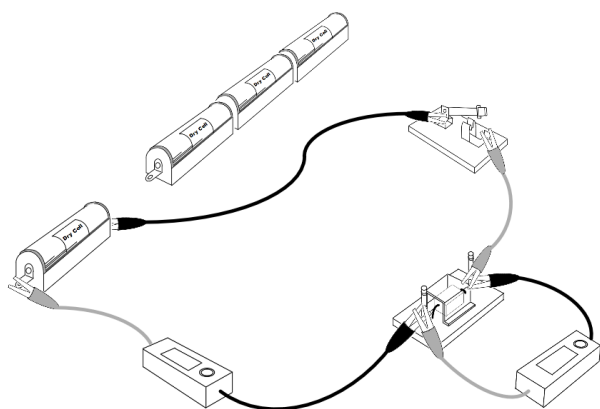

Fig. 1. Simple Circuit

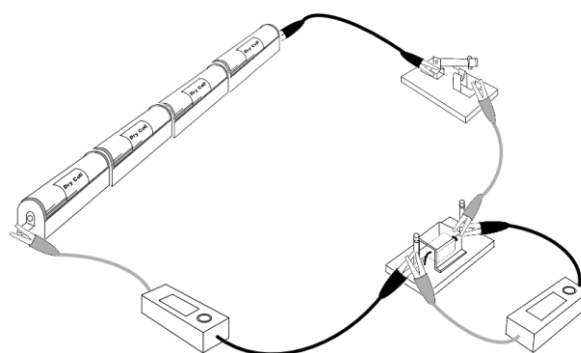Fig. 2. Simple Circuit with one (1) dry cell battery   Fig. 3. Simple Circuit with four (4) dry cell batteries

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Table 1. Voltage and Amperage in Experiment 1

Number of Dry cells	Voltage		Amperage	
1	1.4	V	0.14	A
2	2.6	V	0.26	A
3	3.7	V	0.37	A
4	4.9	V	0.48	A

2. Measuring voltage and ampere of electricity flowing through an electric circuit (2)

1) Assemble a simple circuit as shown in Fig. 1 above with a resistor (20Ω), a dry cell battery, a switch, an ammeter, and a voltmeter.

2) Close the switch to measure the voltage and ampere, and then fill the measurement values in Table 2.

3) Open the switch and add another dry cell to assemble the circuit with two dry cell batteries.

4) Close the switch again to measure the voltage and ampere, and then fill the measurement values in Table 2.

5) Open the switch again to assemble the circuit by increasing the number of dry cell batteries up to four (4). Measure the voltages and amperes in each case of three and four dry cell batteries, and then fill the measurement values in Table 2 (see Fig. 2 and Fig. 3).

Table 2. Voltage and Amperage in Experiment 2

Number of Dry cells	Voltage		Amperage	
1	1.4	V	0.07	A
2	2.7	V	0.13	A
3	3.9	V	0.20	A
4	5.4	V	0.27	A

3. Measuring voltage and ampere of electricity flowing through an electric circuit (3)

1) Assemble a simple circuit as shown in Fig. 1 above with a resistor (30Ω), a dry cell battery, a switch, an ammeter, and a voltmeter.

2) Close the switch to measure the voltage and ampere, and then fill the measurement values in Table 3.

3) Open the switch and add another dry cell to assemble the circuit with two dry cell batteries.

4) Close the switch again to measure the voltage and ampere, and then fill the measurement values in Table 3.

5) Open the switch again to assemble the circuit by increasing the number of dry cell batteries up to four (4). Measure the voltages and amperes in each case of three and four dry cell batteries, and then fill the measurement values in Table 3 (see Fig. 2 and Fig. 3).

Table 3. Voltage and Amperage in Experiment 3

Number of Dry cells	Voltage		Amperage	
1	**1.3**	V	**0.04**	A
2	**2.8**	V	**0.09**	A
3	**4.2**	V	**0.14**	A
4	**5.5**	V	**0.17**	A

4. Draw a graph based on the result of measurement.

1) Plot the data of Table 1 - 3 in Graph 1 below.

2) Draw a straight line extended from the origin (zero point) and passing through the data set of each Table.

3) As each of the straight lines in Graph 1 is drawn as a linear equation ($y = ax$, as $I = y$, $V = x$), gradient (a) of each line can be obtained based on arbitrary point on the line. Fill each gradient (a) in Table 4.
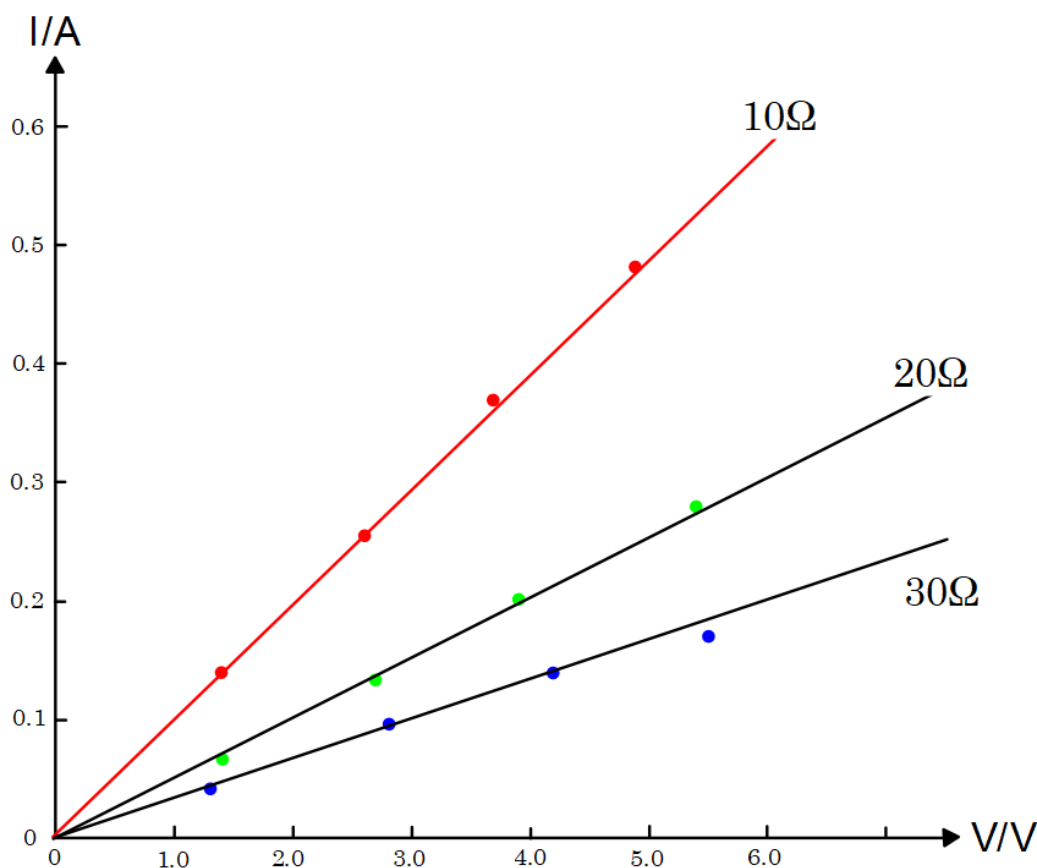
Graph 1. Voltage – Amperage in Experiment 1 - 3

Table4. Gradients of each linear equation in Graph 1.

Experiment	Resistor (Ω)	Gradients (a)
1	10	0.1
2	20	0.05
3	30	0.03

4) Let us summarize the relationship between voltage, amperage, and gradient according to the results shown in Table 4 and Graph 1.

a) Write a general linear equation of the V-I in Graph 1.

$$y = ax \quad ----- \quad ① \quad \text{However, } y = I, \ x = V$$

b) When the gradient in Graph 1 gets steeper, how the value of current changes for a certain voltage?

For a certain voltage, if gradient (a) gets steeper, more current will flow.

Hence, gradient (a) means degree to which current may flow. Order of the gradients shown in

Graph 1 can be ranked as, "Experiment 1 (10 Ω) > Experiment 2 (20 Ω) > Experiment 3 (30

Ω)" that matches the descending order of the values of amperage.

c) Express the relationship between the gradient and resistance shown in Table 4 as a mathematical formula.

The relationship between the gradient and resistance is expressed as a mathematical formula

②, where resistance is "Ω", and the gradient is "a".

$$\Omega = \frac{1}{a} \quad ----- \quad ②$$

The formula shows when the gradient "a" becomes smaller, the resistance "Ω" becomes bigger

and vice versa.

c)   Express the relationship between Voltage (E), Current (I), and Resistance (R) based on the formula ① and ② (when $\Omega = R$).

Formulas ④ and ⑤ (or ③) can be obtained when formulas ① and ② are transformed.

These formulas represent the Ohm's law. $\frac{1}{a} = \frac{x}{y}$ is obtained by formula ① $y = ax$ and its

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transformation $a = \frac{y}{x}$. $\Omega = \frac{x}{y}$ is obtained by formula ② $\Omega = \frac{1}{a}$. By $\Omega = R$, $R = \frac{x}{y}$ is obtained.

By $y = I$. $x = V, R = \frac{V}{I}$ is obtained $\cdots$ ③, where voltage (V) is E, $R = \frac{E}{I}$ $\cdots$ ④,

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or $E = IR$ is obtained. $\cdots$ ⑤

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4. Advanced experiment

Learners will carry advanced experiment to study the relationship between voltage and amperage of electric current flowing through the simple circuit using a miniature bulb instead of a resistor. It is the purpose of this experiment to determine if experimental result from this section will be the same as in the previous experiment.

1. Relationship between voltage and amperage of electric current

1) Assemble a simple circuit with a miniature bulb, an ammeter, a voltmeter, a switch, and dry cell battery (see Fig. 4).
2) Close the switch to measure the voltage and ampere, and then fill the measurement values in Table 5.
3) Open the switch and add another dry cell to assemble the circuit with two dry cell batteries.
4) Close the switch again to measure the voltage and ampere, and then fill the measurement values in Table 5.
5) Open the switch again to assemble the circuit by increasing the number of dry cell batteries up to four (4). Measure the voltages and amperages in each case of three and four dry cell batteries, and then fill the measurement values in Table 5 (see Fig. 4).
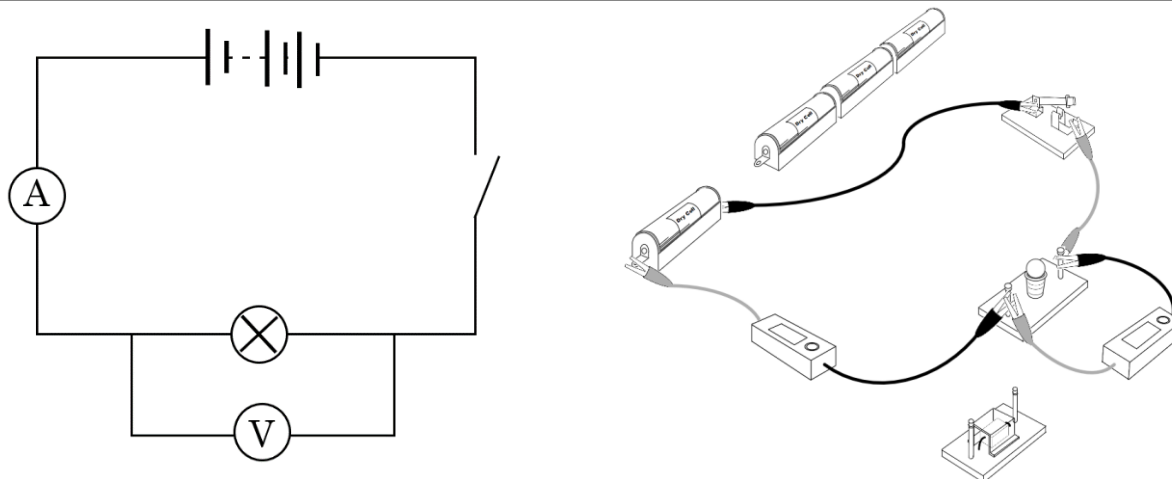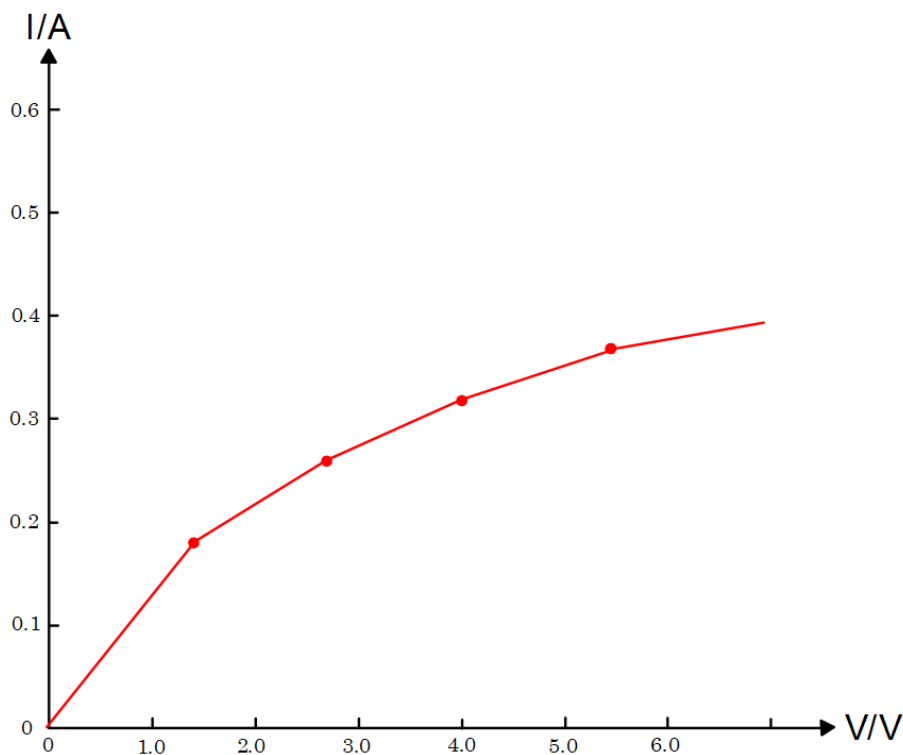
Fig. 4. Simple Circuit with a miniature bulb

Table 5. Voltage and Amperage in Advanced Experiment

Number of Dry cells	Voltage		Amperage	
1	**1.4**	V	**0.18**	A
2	**2.7**	V	**0.26**	A
3	**4.0**	V	**0.32**	A
4	**5.4**	V	**0.37**	A

2. Draw a graph based on the data in Table 5.

1) Plot the data of Table 5 on Graph 2.

2) Draw a polygonal line extended from the origin (zero point).

Graph 2. Voltage – Amperage Graph 2

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3) Describe the reasons why we obtain polygonal (curved) line instead of a straight line.

The miniature bulb (incandescent bulb) gets brighter as its filament glows by being

heated depending on applied voltage. Since the temperature of the filament in the bulb is

increased as more voltage is applied to the circuit, the relation between voltage and amperage

of electric current flowing through the circuit is not proportional to each other because the

resistance value of the filament gets bigger as it is increasingly being heated.

4. Description

This experiment guide is for those learners who have already learned about basic principles of potential difference, electric current, and resistance. The lesson plan of this guide takes an approach that allows learners to induce the Ohm's law through experiments based on which they draw graphs of the relationship between voltage, current, and resistance. Many of the lesson plans commonly available seem to take the approach that allows learners to carry experiments only after they learn about the Ohm's law.

Therefore, this guide leads learners to induce the formula of $R = \frac{V}{I}$ (the Ohm's law) based on

their actual measurement values of voltage and amperage of electric current that flows in the simple circuit at a fixed amount of resistance value.

In that sense, it is important to lead them to be aware that graphs they draw based their actual measurement data is shown in the form of linear function $y = ax$. In other words, instructors lead learners to determine the gradient (a) of each liner function from the graph, to compare each gradient (a) with the resistance value(Ω) in Table 4, and consequently to realize the resistance value (Ω) is given as the reciprocal of the relevant gradient (a).

Practically, learners will induce the Ohm's law $R = \frac{V}{I}$ by following the six steps below:

1) Determine the proportional relationship between the amperage and voltage shown in Graph 1.
2) When voltage is x and amperage is y, Graph 1 is shown in the form of a linear function $y = ax$.
3) The graph indicates that as its gradient (a) gets larger, more electric current flows.
4) Obtain the gradient (a) from the graph (see Table 4).

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5) The reciprocal of the gradient (a) is mostly equivalent to the resistance value shown in Table 4.

6) Formula $y = ax$ is deformed as $\frac{1}{a} = \frac{x}{y}$ via $a = \frac{y}{x}$. As $I = y, V = x$, $R = \frac{V}{I}$ is obtained.

On the other hand, through the advanced experiment with the miniature bulb, learners will recognize that there are some conductive materials that does not obey the Ohm's law, so-called "non-ohmic conductors". According to Graph 2, they will learn that materials like filament used in the miniature bulb actually increase the resistance value with heat. Such materials include thermistors and diodes, each of which has unique graph curve.

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