Physical Experiments II

Experiment Title- Measurement of Resistant by Ammeter Voltmeter Method

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Score

Abstract (About 50 words, 10 points)

The purpose of this experiment is to measure the resistance by Ammeter-outside and Ammeter-inside circuit, analyzing the relationship between the measured resistance and the true resistance. An important part of this experiment which makes it becomes more scientific than what I did at middle school is that analyzing and calculating the relative errors after finishing measuring each set of data.

Score

Calculations and Results (Calculations, data tables and figures, more than 150 words, 20 points)

1. Data Tables

DATA TABLE 1-1(*purpose*: To compute the instrument error and reading error for further calculations of uncertainty and to teach you to read the voltmeter and ammeter correctly)

Apparatus	Voltmeter			Ammeter	
Accuracy class	0.5			0.5	
Range (unit)	1.5V	3V	7.5V	15mA	30mA
Resistance (unit)	300Ω	599Ω	1497Ω	2.1Ω	3.7Ω
Instrument Error (unit)	0.008V	0.02V	0.04V	0.08mA	0.2mA
Reading Error (unit)	0.002V	0.004V	0.01V	0.02mA	0.04mA

(*Don't forget UNITS*)

DATA TABLE 1-2: (*purpose*: To use ammeter outside method to measure resistance with a small value)

Accepted value R_{x1}: 51Ω　　Voltmeter resistance R_V= 599Ω

Rheostat setting	Current, I (mA)		Voltage, V(V)		$R_{x1}=V/I$ (Ω)	$R_{x1}=\frac{V}{I-\frac{V}{R_V}}$ (Ω)
	Range	Instrument error	Range	Instrument error		
	15	0.2	1.5	0.008		
1	4.3		0.191		44.7	48.5
2	11.61		0.511		44.9	49.7
3	13.86		0.601		43.4	47.1
				Average R_{x1}	44.3	48.43
				Relative error	11.3%	5.0%

DATA TABLE 1-3: (*purpose*: To use ammeter inside method to measure resistance with a small value)

Accepted value R_{x1} 51Ω Ammeter resistance R_a= 3.7Ω

Rheostat setting	Current, I (mA)		Voltage, V(V)		$R_{x1}=V/I$ (Ω)	$R_{x1}=\frac{V}{I}-R_a$ (Ω)
	Range	Instrument error	Range	Instrument error		
	15	0.2	1.5	0.008		
1	3.62		0.192		53	49.3
2	9.21		0.501		54	50.3
3	12.53		0.683		54	50.3
				Average R_{x1}	53.67	49.87
				Relative error	5.0%	2.0%

DATA TABLE 1-4: (*purpose*: To Use ammeter outside method to measure resistance with a large value)

Accepted value R_{x2}: 1000Ω Voltmeter resistance R_V= 3.7Ω

Rheostat setting	Current, I (mA)		Voltage, V(V)		$R_{x2}=V/I$ (Ω)	$R_{x2}=\frac{V}{I-\frac{V}{R_V}}$ (Ω)
	Range	Instrument error	Range	Instrument error		
	15	0.08	7.5	0.04		
1	1.00		1.00		1000	996.3
2	2.00		1.95		975	971.3
3	5.97		5.98		1001	997.3
				Average R_{x1}	992	999.3
				Relative error	0.8%	1.1%

DATA TABLE 1-5: (Use ammeter inside method to measure resistance with a large value)

Accepted value R_{x2} 1000Ω Ammeter resistance R_a= 1497Ω

Rheostat setting	Current, I (mA)		Voltage, V(V)		$R_{x2}=V/I$ (Ω)	$R_{x2}=\frac{V}{I}-R_a$ (Ω)
	Range	Instrument error	Range	Instrument error		
	1.5	0.2	7.5	0.04		
1	1.21		1.02		842	845
2	2.34		2.02		863	873
3	7.10		6.17		965	964
				Average R_{x1}	887.0	894.3
				Relative error	11.3%	10.6%

2. Calculations

(1) Show one sample calculation of the instrument error by using the data in Table 1-1.

One sample calculation of the voltmeter with range of 1.5V:

$\Delta Instru. = 0.5\ of\ the\ smallest\ division$=0.5*0.016V=0.008V

(2) Use the last set of data in Table 1-2 to show the sample calculation of the approximate resistance and the corrected resistance.

The sample calculation of the approximate resistance:

$$R_v = 599(\Omega)$$

$$R_{x1} = \frac{V}{I} = 44.7(\Omega)$$

$$R_{x2} = \frac{V}{I} = 44.9(\Omega)$$

$$R_{x3} = \frac{V}{I} = 43.4(\Omega)$$

$$R_{average} = (R_{x1} + R_{x2} + R_{x3}) \div 3 = 44.3(\Omega)$$

The sample calculation of the corrected resistance:

$$R_v = 599(\Omega)$$

$$R'_{x1} = \frac{V}{I - \frac{V}{R_V}} = 48.5(\Omega)$$

$$R'_{x2} = \frac{V}{I - \frac{V}{R_V}} = 49.7(\Omega)$$

$$R'_{x3} = \frac{V}{I - \frac{V}{R_V}} = 47.1(\Omega)$$

$$R_{average'} = (R'_{x1} + R'_{x2} + R'_{x3}) \div 3 = 48.43(\Omega)$$

(3) Follow the steps to find the uncertainty for the first set of measurement in Table 1-2.

a) Use the measured voltage and current to calculate the magnitude of resistance.

$$R_{x1} = \frac{V}{I} = 44.3\Omega$$

b) To find the type A uncertainty in current *I*, $\mu_{A\text{-}I}$.

$$\mu_{A-I} = \sqrt{\frac{1}{N(N-1)}\sum_{i=1}^{N}(I_i - \bar{I})^2} = \sqrt{\frac{1}{3(3-1)}\sum_{i=1}^{3}(I_i - \bar{I})^2} =$$

$$\sqrt{\frac{1}{3(3-1)}[(4.3\text{mA} - 9.92\text{mA})^2 + (11.61\text{mA} - 9.92\text{mA})^2 + (13.86\text{mA} - 9.92\text{mA})^2]}$$

$$= \sqrt{\frac{1}{3(3-1)}[35.05 + 2.86 + 15.52]}\text{mA}=2.98\text{mA}$$

c) To find the type B uncertainty in current *I*, $\mu_{B\text{-}I}$.

$$\mu_{\Delta\ Instru.-I} = \frac{\Delta_{Instr.-I}}{\sqrt{3}} = \frac{0.5\%*15mA}{\sqrt{3}}=0.434\text{ mA}$$

$$\mu_{\Delta\ Read.-I} = \frac{\Delta_{Read.-I}}{\sqrt{3}} = \frac{0.02mA}{\sqrt{3}}=0.0116\text{mA}$$

$$\mu_{B-I} = \sqrt{\mu_{\Delta Instru.-I}^2 + \mu_{\Delta Read.-I}^2}=\sqrt{(0.434mA)^2 + (0.0116mA)^2}=0.434\text{mA}$$

d) To find the combined uncertainty in current *I*, σ_I.

$$\sigma_I = \sqrt{\mu_{A-I}^2 + \mu_{B-I}^2}=\sqrt{(0.434mA)^2 + (2.98mA)^2}=3.011\text{mA}$$

e) To find the type A uncertainty in voltage *V*, $\mu_{A\text{-}V}$.

$\mu_{A-V} =$

$\sqrt{\frac{1}{N(N-1)}\sum_{i=1}^{N}(V_i-\bar{V})^2}=$

$\sqrt{\frac{1}{3(3-1)}[(0.191\mathrm{V}-0.434\mathrm{V})^2+(0.511\mathrm{V}-0.434\mathrm{V})^2+(0.601\mathrm{V}-0.434\mathrm{V})^2]}=$

$\sqrt{\frac{1}{3(3-1)}(0.059+0.0059+0.028)}V$=0.124V

f) To find the type B uncertainty in voltage *V*, $\mu_{B\text{-}V}$.

$$\mu_{\Delta\ Instru.-V} = \frac{\Delta_{Instr.-V}}{\sqrt{3}} = \frac{0.008V}{\sqrt{3}} = 0.0046V$$

$$\mu_{\Delta\ Read.-V} = \frac{\Delta_{Read.-V}}{\sqrt{3}} = \frac{0.002V}{\sqrt{3}} = 0.0012V$$

$$\mu_{B-V} = \sqrt{\mu_{\Delta Instru.-V}^2 + \mu_{\Delta Read.-V}^2} = \sqrt{(0.0046)^2+(0.0012)^2}V = 0.00474\mathrm{V}$$

g) To find the combined uncertainty in voltage *V*, σ_V.

$$\sigma_V = \sqrt{\mu_{A-V}^2+\mu_{B-V}^2} = \sqrt{(0.124)^2+(0.00474)^2}V = 0.0154V$$

h) Compute the relative uncertainty in resistance R_{x1}.

$\frac{\sigma_{R_{x1}}}{|R_{x1}|} = \sqrt{(\frac{\sigma_V}{V})^2+(\frac{\sigma_I}{I})^2} = \sqrt{(\frac{0.0154}{0.434})^2+(\frac{3.011}{9.92})^2} = \sqrt{0.00126+0.0921}$=0.30

$\sigma_{R_{x1}} = |R_{x1}|\times\frac{\sigma_{R_{x1}}}{|R_{x1}|}$=44.3*0.30=13.5Ω

Score

Answers to Questions (10 points)

（1）To measure a small resistance, the error of using Ammeter-inside circuit is larger than the error of using Ammeter-outside circuit.

（2）To measure a large resistance, the error of using Ammeter-inside circuit is smaller than the error of using Ammeter-outside circuit.

（3）It depends on the value of the resistance. If the resistance with large resistance, using the Ammeter-inside circuit (Fig 3.1-3) would have the smallest error, since the resistance of ammeter is small and influence slightly, which can be even ignored. If the resistance with small resistance, using the Ammeter-outside circuit (Fig 3.1-2), since the resistance of ammeter is close to the measured resistance and influence a lot, which can not be ignored.

(4) The accepted resistance lie in the range is not determined by the magnitude of the resistance and its uncertainty. Because if we using the proper method and following the right steps, the value will lie in the range according the normal distribution.

(5) Because if we do not choose the ideal situation, we will consider the real resistance of the ammeter and voltmeter which means we have to spend more time following the complex calculation steps.

(6) Diode has the reverse characteristic which means when the reverse voltage is lower than the reverse breakdown voltage, the reverse resistance is very large and the reverse current is very small. However, when the reverse voltage approaches the critical value of the reverse voltage, the reverse current suddenly increases, which is called breakdown, and the reverse resistance suddenly drops to a small value. Although the current varies in a wide range, the voltage of the diode is stable about the breakdown voltage. And the manostat is also called the voltage regulator, which plays a stabilizing role in the output voltage by regulating transformer.

Appendix

(Scanned data sheets)

3.1.5 Experimental Data

Data Table 3.1-1 ***Purpose*** **: To compute the instrument error and reading error for further calculations of uncertainty and to learn to read the voltmeter and ammeter correctly**

Apparatus	Voltmeter			Ammeter	
Accuracy class	0.5			0.5	
Range (unit)	1.5V	3V	7.5V	15mA	30mA
Resistance (unit)	300Ω	599Ω	1497Ω	2.1Ω	3.7Ω
Instrument Error (unit)	0.008V	0.02V	0.04V	0.08mA	0.2mA
Reading Error (unit)	0.002V	0.004V	0.01V	0.02mA	0.04mA

最小精度

(Don't forget UNITS)

Data Table 3.1-2 ***Purpose*****: To use ammeter outside method to measure resistance with a small value**

Accepted value R_{x1}: 51Ω Voltmeter resistance R_v= 599Ω

Rheostat setting	Current, I/mA		Voltage, V/V		$R_{x1}=V/I$ /Ω	$R'_{x1}=\frac{V}{1-\frac{V}{R_v}}$ /Ω
	Range	Instrument error	Range	Instrument error		
	15mA	0.2mA	1.5V	0.008V		
1	4.3 mA		0.191 V		44.7	48.5
2	11.61 mA		0.511 V		44.9	49.7
3	13.86 mA		0.601 V		43.4	47.1
	9.92		0.434	Average	44.3	48.43
				Relative error	11.3%	5.0%

large

Data Table 3.1-3 ***Purpose*****: To use ammeter inside method to measure resistance with a ~~small~~ value**

Accepted value R_{x1} 1000Ω Ammeter resistance R_a= 3.7Ω

Rheostat setting	Current, I/mA		Voltage, V/V		$R_{x1}=V/I$ /Ω	$R'_{x1}=\frac{V}{I}-R_a$ /Ω
	Range	Instrument error	Range	Instrument error		
	15mA	0.08mA	7.5V	0.04V		
1	1.00mA		1.00 V		1000	996.3
2	2.00 mA		1.95 V		975	971.3
3	5.97mA		5.98 V		1001	997.3
				Average	992	988.3
				Relative error	0.8%	1.1%

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Data Table 3.1-4 ***Purpose*: To use ammeter outside method to measure resistance with a large value**

Accepted value R_{x2}: 1000 Ω, Voltmeter resistance R_V= 1497 Ω

Rheostat setting	Current, I/mA		Voltage, V/V		$R_{x1}=V/I$ /Ω	$R'_{x2}=\frac{V}{1-\frac{V}{R_v}}$ /Ω
	Range	Instrument error	Range	Instrument error		
	1.5	0.2	7.5	0.04		
1	1.21		1.02		842	845
2	2.34		2.02		863	873
3	7.10		6.17		965	964
				Average	887	894.3
				Relative error	11.3%	10.6%

Data Table 3.1-5 ***Purpose*: To use ammeter inside method to measure resistance with a ~~large~~ small value**

Accepted value R_{x2} 51 Ω, Ammeter resistance R_a= 3.1 Ω

Rheostat setting	Current, I/mA		Voltage, V/V		$R_{x2}=V/I$ /Ω	$R'_{x2}=\frac{V}{I}-R_a$ /Ω
	Range	Instrument error	Range	Instrument error		
	15	0.2	1.5	0.008		
1	3.62		0.192		53.0	49.3
2	9.21		0.501		54.0	50.3
3	12.53		0.683		54.0	50.3
				Average	53.67	49.87
				Relative error	5.0%	2.0%

***NOTE*: The following measurements are optional.**

Data Table 3.1-6 ***Purpose*: To measure the normal resistance of a diode**

V/V	0.000	0.100	0.200	0.300	0.400						
I/mA						5.0	10.0	15.0	20.0	25.0	30.0

Data Table 3.1-7 ***Purpose*: To measure the reverse resistance of a diode**

V/V	0.00	1.00	2.00	2.50	3.00						
I/mA						5.0	10.0	15.0	20.0	25.0	30.0

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