UESTC Student Number: 2016200302027 Email: 1558241660@qq.com Date: 20th May

# Physical Experiment I

Experimental Title

Measurement of Resistant by Ammeter Voltmeter Method

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Date Performed: 20th may

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## **Abstract** (About 100 words, 10 points)

This experiment is for measuring of the resistance and the main point of this experiment is to know the difference of the result when the circuit is inter-connected or exter-connected. Actually, this is the second time we did this experiment but what we did is very different from what we had done at high school. The most difference is in data processing procedure. The error in measuring of resistance by the V-A method is analyzed when the circuit is inter-connected or exter-connected. Then, we filled these data in the form and got the relative error of the answer.

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## **Calculations and Results** (Calculations, data tables and figures; Use about 100 words to describe your results, 20 points)

(1) Show one sample calculation of the instrument error by using the data in Data Table 3.1-1

$\Delta Instru. = 0.5\ of\ the\ smallest\ division$=0.016*0.5=0.008(V)-----(range 1.5V voltmeter)

(2) Use the last set of data in Data Table 3.1-2 to show the sample calculation of the approximate resistance and the corrected resistance.

We use the following method to get the approximate.

$$R_v = 299(\Omega)$$

$R_{x1} = \frac{V}{I} = 45.8(\Omega)$-------(the sample of the first measurement)

$R_{x2} = \frac{V}{I} = 45.5(\Omega)$-------(the sample of the second measurement)

$R_{x3} = \frac{V}{I} = 45.1(\Omega)$-------(the sample of the third measurement)

$$R_{average} = \left(R_{x1} + R_{x2} + R_{x3}\right) \div 3 = 45.5(\Omega)$$

We use the following method to get the correct.

$$R_v = 299(\Omega)$$

$R'_{x1} = \frac{V}{I - \frac{V}{R_V}} = 54.1(\Omega)$-------(the sample of the first measurement)

$R'_{x2} = \frac{V}{I - \frac{V}{R_V}} = 53.7(\Omega)$-------(the sample of the second measurement)

$R'_{x3} = \frac{V}{I - \frac{V}{R_V}} = 53.1(\Omega)$-------(the sample of the third measurement)

$$R_{average'} = \left(R'_{x1} + R'_{x2} + R'_{x3}\right) \div 3 = 53.7(\Omega)$$

(3) Follow the steps below to find the uncertainty of the first set of measurement in Data Table 3.1-2.

a. $R_{x1} = \frac{V}{I} = 45.5\Omega$

b.

$$\mu_{A-I} = \sqrt{\frac{1}{N(N-1)}\sum_{i=1}^{N}(I_i - \bar{I})^2} = 0.00312(A)$$

$$\mu_{\Delta_{\text{Instru.}-\text{I}}} = \frac{\Delta_{\text{Instru.}-\text{I}}}{\sqrt{3}} = 0.000115(A)$$

$$\mu_{\Delta_{\text{Read.}}-I} = \frac{\Delta_{\text{Read.}-\text{I}}}{\sqrt{3}} = 0.0000231(A)$$

$$\mu_{B-I} = \sqrt{\mu^2_{\Delta_{\text{Instru.}-\text{I}}} + \mu^2_{\Delta_{\text{Read.}-\text{I}}}} = 0.000117(A)$$

$$\sigma_I = \sqrt{\mu^2_{B-I} + \mu^2_{A-I}} = 0.00312(A)$$

$$\mu_{A-V} = \sqrt{\frac{1}{N(N-1)}\sum_{i=1}^{N}(V_i - \bar{V})^2} = 0.140(V)$$

$$\mu_{\Delta_{\text{Read.}}-V} = \frac{\Delta_{\text{Read.}-\text{V}}}{\sqrt{3}} = 0.00115(V)$$

$$\mu_{\Delta_{\text{Instru.}}-V} = \frac{\Delta_{\text{Instru.}-\text{V}}}{\sqrt{3}} = 0.00462(V)$$

$$\sigma_V = \sqrt{\mu_{A-V}^2 + \mu_{A-V}^2} = 0.00476(V)$$

$$\frac{\sigma_{R_{x1}}}{|R_{x1}|} = \sqrt{(\frac{\sigma_V}{V})^2 + (\frac{\sigma_I}{I})^2} = 0.0123$$

$$\sigma_{R_{x1}} = |R_{x1}| \times \frac{\sigma_{R_{x1}}}{|R_{x1}|} = 0.559(\Omega)$$

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## Answers to Questions (10 points)

**(1) After computing Data Table 3.12 and 3.13, what conclusion can you draw.**

If we use the ammeter inside method to measure a small resistance, the error would be bigger than that of using ammeter outside method.

**(2) After computing Data Table 3.14 and 3.15, what conclusion can you draw.**

If we use the ammeter outside method to measure a huge resistance, the error would be much bigger than that of using ammeter inside method.

**(3) If in general R were calculated as R=V/I, which circuit arrangement in Fig 3.1-2 and Fig 3.1-3 would have the smallest**

**error? Explain.**

It depends, If R is a resistance with huge resistance, we should use the ammeter inside method (Fig 3.1-3), as the resistance of ammeter is small and influence little to the final R, which can be ignored directly. If R is a normal resistance, we should use the ammeter outside method (Fig 3.1-2), as the resistance of ammeter is close to R and influence a lot to the final R, which can not be ignored directly.

(4) **In the conclusion section, you use the equation R=V/I and the, measurements to compute the magnitude of the resistance and its uncertainty. Does the accepted resistance lie in the range determined by the magnitude of the resistance and its uncertainty? Why?**

Because the experiment results follow normal distribution, and the method we use ensures that the answer will in that range by a 95.4 percent ($\bar{x} + n\sigma$).

If we use the right method to measure the resistance, the answer would normally in that range.

(5) **An ideal ammeter would have zero resistance, and an ideal voltmeter would have an infinite resistance. Explain why we would desire these ideal cases when using the meters.**

We won't think about method errors caused by measuring instruments when measure resistance during daily life, and we always ignore method errors actually. So, we wish the inside resistanc of an ammeter as small as possible and the inside resistance of a voltmeter as big as possible, so that the measuring result will be closest to the true value.

**(6) Why can a diode be applied as the core component of a manostat ?**

Diode is used as a kind of voltage regulator, it makes use of PN junction breakdown area, which makes it has the characteristics of stable for the voltage. The diode has the characteristic which is even if it is breakdown, the voltage at the two ends still remain unchanged. So, when the voltage regulator tube access circuit, due to the power supply voltage fluctuations, or other causes circuit fluctuates, the voltage changes between two ends will remain unchanged. When the diode reverse breakdown, although the current changes in a large scale, the voltage variation would be small between both ends .So it can be used as voltage regulator.

# Appendix

## (Scanned data sheets)

3. EXPERIMENTS

### 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 | 15 mA | 30mA |
| Resistance (unit) | 2PPΩ | 5PPΩ | 14P7Ω | 2.1Ω | 3.7Ω |
| Instrument Error (unit) | 0.008V | 0.02V | 0.04V | 0.08 mA | 0.2 mA |
| Reading Error (unit) | 0.002V | ~~0.04~~ 0.004V | 0.01V | 0.02 mA | 0.04 mA |

(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 $R_V$= 2PPΩ

| 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 | | |
| | 30mA | 0.2mA | 1.5 | 0.008V | | |
| 1 | 7.2 mA | | 0.063001 | 0.330 V | 45.8 | 54.13 |
| 2 | 13.2 mA | | 0-0004 | 0.601 V | 45.5 | 53.71 |
| 3 | 18.0 mA | | 0-053361 | 0.812 V | 45.1 | 53.13 |
| | | | | Average | 45.5 | 53.65 |
| | | | | Relative error | −11% | 5.1% |

0.00002704

12.8

0.581

0.0000016

0.00003136

**Data Table 3.1-3** ***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 | | |
| | 30mA | 0.2 mA | 1.5V | 0.008V | | |
| 1 | 7.2 mA | | | 0.400 V | 55.6 | 51.84 |
| 2 | 10.0 mA | | | 0.555 V | 55.5 | 51.86 |
| 3 | 13.0 mA | | | 0.720 V | 55.4 | 51.73 |
| | | | | Average | 55.5 | 51.82 |
| | | | | Relative error | 8.8% | 1.6% |

>1% ~ 2位有效数字

<1% ~ 1位

Your name and student number:__________ Instructor's initial: Gao

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

Accepted value $R_{x2}$: 1KΩ ; Voltmeter resistance $R_V$= 1497Ω

| 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 | 0.08 | 7.5 | 0.04 | | |
| 1 | 2.25 | | 1.40 | | 622.2 | 1065 |
| 2 | 4.19 | | 2.60 | | 620.5 | 1060 |
| 3 | 6.71 | | 4.18 | | 623.0 | 1067 |
| | | | | Average | 621.9 | 1064 |
| | | | | Relative error | −38% | 6.4% |

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

Accepted value $R_{x2}$ 1kΩ Ammeter resistance $R_a$= 2.1Ω

| 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 | 0.08 | 7.5 | 0.04 | | |
| 1 | 1.49 | | 1.54 | | 1034 | 1032 |
| 2 | 2.25 | | 2.31 | | 1027 | 1025 |
| 3 | 4.59 | | 4.75 | | 1035 | 1033 |
| | | | | Average | 1032 | 1030 |
| | | | | Relative error | 3.2% | 3.0% |

***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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