

**SCHOOL OF PHYSICS**

**UNIVERSITI SAINS MALAYSIA**

**ZCT191/192 PHYSICS PRACTICAL I/II**

**ERROR ANALYSIS**

***Worksheets***

**OBJECTIVES**

1. *To* *understand how to correctly present a physical quantity with its error;*
2. *To estimate the resistivity of a copper wire and its error by measuring its length, resistance and diameter; and*
3. *To study the probability distribution function of the diameter of a copper wire.*

**ERROR ANALYSIS WORKSHEET 1**

*Instructions*: please complete **Worksheet 1** by the end of the first session of your experiment.

Name : \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date : \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Partner’s Name : \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Group : \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Part A1: Length of a Copper Wire**

**Table 1**: The length of the copper wire.

|  |  |  |  |
| --- | --- | --- | --- |
| **Measurement,** | **Length of wire,**  **0.1** | **(m)** | **()** |
| 1 | 129.5 | -1.875 | 3.51563 |
| 2 | 130.0 | 3.125 | 9.76563 |
| 3 | 129.8 | 1.125 | 1.26563 |
| 4 | 129.7 | 0.125 | 1.56250 |
| 5 | 129.7 | 0.125 | 1.56250 |
| 6 | 129.4 | -2.875 | 8.26562 |
| 7 | 129.7 | 0.125 | 1.56250 |
| 8 | 129.7 | 0.125 | 1.56250 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | Sample size, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
|  | Standard deviation, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  | Length of copper wire, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |

**Part A2: Resistance of Copper Wire**

**Table 2**: The resistance of the copper wire.

|  |  |  |  |
| --- | --- | --- | --- |
| **Measurement,** | **Resistance of wire,**  **0.1** | **(Ω)** | **()** |
| 1 | 0.8 | -0.05 | 0.0025 |
| 2 | 0.8 | -0.05 | 0.0025 |
| 3 | 0.9 | 0.05 | 0.0025 |
| 4 | 0.8 | -0.05 | 0.0025 |
| 5 | 0.9 | 0.05 | 0.0025 |
| 6 | 0.9 | 0.05 | 0.0025 |
| 7 | 0.8 | -0.05 | 0.0025 |
| 8 | 0.9 | 0.05 | 0.0025 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | Sample size, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Ω |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
|  | Standard deviation, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Ω |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Ω |
|  | Resistance of copper wire, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Ω |

**Part A3: Diameter of Copper Wire**

**Table 3**: The diameter of the copper wire.

|  |  |  |  |
| --- | --- | --- | --- |
| **Measurement,** | **Diameter of wire,** | **(m)** | **()** |
| 1 | 0.21 | 2.5 | 6.25 |
| 2 | 0.23 | 2.25 | 5.0625 |
| 3 | 0.20 | -7.5 | 5.625 |
| 4 | 0.19 | -1.75 | 3.0625 |
| 5 | 0.17 | -3.75 | 1.40625 |
| 6 | 0.23 | 2.25 | 5.0625 |
| 7 | 0.20 | -7.5 | 5.625 |
| 8 | 0.23 | 2.25 | 5.0625 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | Zero error | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  | Sample size, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
|  | Standard deviation, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  | Diameter of copper wire, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  | Diameter of copper wire (lab reference book), | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ % |

**Analysis**

Fill in the blanks with the correct answers, uncertainties and units.

The measured values of the length (), resistance () and diameter () of the SWG36 copper wire are

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

The best estimate of the resistivity of the copper wire is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.  
*[Show your calculations in the space provided below. Use the correct units in your final answer.]*

|  |
| --- |
|  |

The uncertainty of the resistivity of the copper wire is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show your calculations in the space below. Hint: use the variance formula from the guidebook.]*

|  |
| --- |
|  |

The final estimated resistivity of the SWG36 copper wire is therefore   
\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

The temperature in the first year lab is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

The standard values of the resistivity for the SWG36 copper wire SWG 36 at different temperatures are

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Plot of vs. :

|  |
| --- |
|  |

**Figure 1**: Plot of vs. .

From the graph, the estimated standard resistivity of a copper wire at laboratory temperature is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

The percentage discrepancy between the standard resistivity and the experimental resistivity of the copper wire is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show your calculations in the space below, and comment if your result is accurate.]*

|  |
| --- |
|  |

1. The sources of systematic errors observed in this experiment are:

*[Comment if they are significant.]*

|  |
| --- |
|  |

1. Other sources of errors in this experiment include:

*[List down at least three sources, and explain briefly how these errors affected your results.]*

|  |
| --- |
|  |

1. The fractional uncertainty of the measured resistivity of the SWG36 copper wire is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show your calculations in the space below, and comment if your result is precise.]*

|  |
| --- |
|  |

1. The precision of the resistivity measurement can improve if

*[List down at least three suggestions.]*

|  |
| --- |
|  |

**Conclusion**

1. The resistivity of the copper wire at temperature \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
2. The agreement between experimental and standard values is good / not good\*. The systematic errors are significant / insignificant\*.

*[\*Strike out whichever is not applicable.]*

**ERROR ANALYSIS WORKSHEET 2**

*Instructions*: please complete **Worksheet 2** by the end of the second session of your experiment.

Name : \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date : \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Partner’s Name : \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Group : \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Data**

**Table 4**: Diameter () measurements of the copper wire for samples to 40. Students are required to obtain three samples of readings only, as the remaining 37 samples have been provided for you.

|  |  | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **1** |  |  |  |  |  |  |  |  |
| **2** |  |  |  |  |  |  |  |  |
| **3** |  |  |  |  |  |  |  |  |
| **4** | 196 | 206 | 191 | 193 | 192 | 190 | 195 | 193 |
| **5** | 197 | 193 | 193 | 198 | 188 | 191 | 191 | 195 |
| **6** | 203 | 201 | 196 | 195 | 196 | 197 | 193 | 189 |
| **7** | 201 | 205 | 203 | 197 | 196 | 189 | 197 | 200 |
| **8** | 200 | 195 | 193 | 196 | 201 | 188 | 196 | 195 |
| **9** | 195 | 201 | 206 | 198 | 196 | 194 | 189 | 198 |
| **10** | 194 | 198 | 199 | 198 | 196 | 206 | 196 | 198 |
| **11** | 201 | 199 | 193 | 191 | 190 | 189 | 190 | 188 |
| **12** | 192 | 190 | 191 | 197 | 190 | 189 | 193 | 188 |
| **13** | 197 | 198 | 200 | 199 | 206 | 198 | 195 | 200 |
| **14** | 191 | 190 | 198 | 196 | 196 | 201 | 196 | 196 |
| **15** | 194 | 205 | 202 | 203 | 197 | 191 | 193 | 199 |
| **16** | 199 | 195 | 198 | 199 | 205 | 206 | 208 | 192 |
| **17** | 204 | 196 | 199 | 199 | 192 | 193 | 196 | 197 |
| **18** | 193 | 200 | 191 | 191 | 192 | 199 | 203 | 198 |
| **19** | 196 | 193 | 193 | 203 | 205 | 194 | 194 | 199 |
| **20** | 199 | 193 | 195 | 188 | 199 | 199 | 197 | 190 |
| **21** | 197 | 194 | 191 | 195 | 195 | 195 | 203 | 206 |
| **22** | 197 | 196 | 200 | 197 | 198 | 195 | 194 | 195 |
| **23** | 190 | 197 | 189 | 195 | 193 | 195 | 197 | 189 |
| **24** | 195 | 197 | 196 | 199 | 205 | 195 | 198 | 196 |
| **25** | 191 | 194 | 197 | 198 | 199 | 200 | 199 | 194 |
| **26** | 201 | 193 | 196 | 197 | 192 | 196 | 198 | 198 |
| **27** | 191 | 197 | 195 | 196 | 187 | 195 | 197 | 202 |
| **28** | 197 | 197 | 193 | 201 | 195 | 193 | 193 | 193 |
| **29** | 196 | 193 | 199 | 199 | 191 | 195 | 191 | 195 |
| **30** | 203 | 206 | 195 | 195 | 189 | 195 | 197 | 195 |
| **31** | 193 | 203 | 201 | 201 | 195 | 205 | 196 | 199 |
| **32** | 196 | 192 | 196 | 201 | 195 | 196 | 197 | 196 |
| **33** | 196 | 195 | 197 | 198 | 195 | 197 | 199 | 195 |
| **34** | 200 | 196 | 206 | 193 | 195 | 192 | 198 | 192 |
| **35** | 196 | 201 | 196 | 199 | 193 | 201 | 197 | 209 |
| **36** | 196 | 195 | 195 | 195 | 196 | 198 | 197 | 195 |
| **37** | 197 | 195 | 194 | 196 | 196 | 200 | 198 | 198 |
| **38** | 193 | 194 | 190 | 193 | 194 | 190 | 196 | 195 |
| **39** | 195 | 197 | 195 | 199 | 193 | 196 | 193 | 213 |
| **40** | 192 | 196 | 193 | 192 | 196 | 199 | 198 | 194 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | Sample size, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ |
|  | Standard deviation, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  |  | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |
|  | Diameter of copper wire, | : | \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ m |

**Table 5**: The frequency distribution for the diameter readings of the copper wire.

|  |  |  |
| --- | --- | --- |
| **Bin Ranges ()**  **[E.g. 185.5 – 187.5]** | **Number of Readings,** | **Ratio,**  **(Total Sample Size, 320\_)** |
| 186.5-188.5 | 6 | 0.01875 |
| 188.5-190.5 | 36 | 0.1125 |
| 190.5-192.5 | 25 | 0.078125 |
| 192.5-194.5 | 42 | 0.13125 |
| 194.5-196.5 | 81 | 0.253125 |
| 196.5-198.5 | 51 | 0.159375 |
| 198.5-200.5 | 36 | 0.1125 |
| 200.5-202.5 | 15 | 0.046875 |
| 202.5-204.5 | 9 | 0.028125 |
| 204.5-206.5 | 14 | 0.04375 |
| 206.5-208.5 | 1 | 0.003125 |
| 208.5-210.5 | 2 | 0.00625 |
| 210.5-212.5 | 0 | 0 |
| 212.5-214.5 | 1 | 0.003125 |
| 214.5-216.5 | 0 | 0 |
| 216. 5-218.5 | 0 | 0 |
| 218.5-220.5 | 1 | 0.003125 |

|  |
| --- |
| Place your histogram in this blank area. Draw a Gaussian curve on the histogram. |

**Figure 2**: Histogram of vs. .

**Analysis**

1. The maximum point of the histogram is located at \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, with a value of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
2. The percentage difference between and is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show your calculations in the space below, and comment if your results are consistent with each other.]*

|  |
| --- |
|  |

1. The area under the Gaussian curve is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show your workings below.]*

|  |
| --- |
|  |

1. The standard deviation () of the sketched Gaussian curve is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show all the steps that you have used to obtain the answer.]*

|  |
| --- |
|  |

1. The percentage difference between the standard deviation obtained using statistical analysis () and the standard deviation obtained using a best-fit Gaussian curve () is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show your calculations in the space below, and comment if your results are consistent with each other. Determine which is a more appropriate standard deviation for the diameter of the copper wire, and if the sample distribution approximates a Gaussian distribution well.]*

|  |
| --- |
|  |

In a normal experiment, you will not have sufficient time to collect 40 sets of data with 8 readings for each set to make the above estimation of mean and standard deviation. Usually, only one set of data is obtained, and all the errors will be estimated from this set of data.

1. Taking only data from sample from **Table 4**, The best estimate of the diameter of the copper wire is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, which is within \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ percentage difference from calculated using all 40 samples.

*[Show your workings below, and comment if both results are consistent with one another.]*

|  |
| --- |
|  |

1. The fractional uncertainties of and are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, respectively.

*[Show your workings below, and determine which measurement is more precise.]*

|  |
| --- |
|  |

1. By using the value of calculated using all 40 samples, and the values of and calculated in **Part A**, the best estimate of the resistivity of the copper wire is   
    \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show all the steps that you have used to obtain the answer.]*

|  |
| --- |
|  |

1. By using and obtained in **Part A** as well as obtained in **Part B**, the uncertainty of the resistivity of the copper wire is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show all the steps that you have used to obtain the answer.]*

|  |
| --- |
|  |

1. The final estimated resistivity of the SWG36 copper wire at temperature \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
2. The percentage difference between the resistivity obtained in **Part A** and **Part B** is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

*[Show your workings below, and comment if the results are consistent with each other.]*

|  |
| --- |
|  |

1. From **Figure 1**, the standard resistivity value for the SWG36 copper wire at the same temperature is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, which is within \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ percentage discrepancy with the results obtained in **Part B**.

*[Show your workings below, and comment if your result is accurate.]*

|  |
| --- |
|  |

**Conclusion**

1. The resistivity of the copper wire at temperature \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
2. The percentage discrepancy between the standard and measured values of is significant / insignificant\*.

*[\*Strike out whichever is not applicable.]*