Lab Reports, Errors and Significant Figures

PHYS 1003 Fall 2019

Lab Report Formatting

- Must be **neat** and **organized**
  - Handwritten and/or typed – it's up to you
  - If choose to print: https://carleton.ca/cuonthego/
  - No page limit
  - Number your pages

- Use **proper grammar**
  - Full, complete sentences
  - Formal vocabulary, correct spelling, no abbreviations
    - Your report shouldn't read like a text message
  - **NO POINT FORM**

- When **reporting values**:
  - Units
  - Errors (where appropriate)
  - Significant Figures

- **Tables** and **Figures**
  - Numbers
  - Captions

Under ***General Information*** on cuLearn:

- ***Section B:*** details on report writing
- ***Sample Lab Report:*** example of a report

Copying, plagiarism and any other type of cheating will automatically result in a score of 0%. A report will be sent to the Dean of the Faculty.

Plagiarism

Plagiarism

- Submitting work written whole or in part by someone else
- Failing to acknowledge sources through the use of proper citations when using another's work

Test and Exam Rules

- Attempting to read another student's exam papers
- Speaking to another student (even if subject matter is irrelevant to text)
- Using material not authorized by the examiner

Other Violations

- Improper access to confidential information such as exams or test questions
- Disruption of classroom activities or periods of instruction
- Misrepresentation of facts for any academic purpose

Cover Page

Carleton University

Laboratory Report

Course #: PHYS 1008 **Experiment #:** 1

DC Circuits

John Doe
(100123456)

Date Performed: July 12, 2017
Date Submitted: July 19, 2017
Lab Period: Wednesday EVE, A1
Partner: Frank Smith
Station #: 24
TA: Lisa

Template available on cuLearn under *General Information*

- **Include on the cover:**
  - Course #
  - Experiment #
  - Experiment Title
  - Date Performed
  - Date Submitted
  - Lab period (eg. Friday AM)
  - Your name
  - Your partner's name
  - Your TA's name

NOTE: will loose marks if information is incomplete

Marking

Lab Report Sections	Marks
Purpose	2
Theory	5
Apparatus	3
Observations/Graphs	65 marks (breakdown specific to experiment, will **not** be provided)
Calculations	
Results	5
Discussion	20 **(0/20 for 'Human Error')**
Raw Data	**Up to 0 on report if missing**
Neatness/overall quality	Additional penalty
Late Penalty	**-30%**

Use your time wisely – spend more time on the section that are worth more!

Purpose

- **Specific** aim of experiment
  - What will you be looking for and how will you go about finding it
- A few sentences

	
"The purpose of the lab is to study electricity."	"The purpose of the experiment is to determine the equivalent resistance for parallel and series resistor combinations using two approaches: mathematical and direct measurements. In the mathematical method the nominal resistance values will be used to calculate the expected equivalent resistance of a given resistor combination. This value will then be verified by using an ohmmeter to perform a direct measurement for the connected resistor combination."

Theory

- 1 or 2 short paragraphs
  - Don't try to re-write the entire theory section from the manual
- Be able to identify and explain the **key equations** – the ones that the experiment is based on.
  - Physics behind them
    - Limitations/assumptions
      - Meaning of variables

Example	
Important (Key) = **Include** ✓	Not Important = **Don't include** ✗
$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$	$\sigma_{R_{eq}} = \sqrt{\frac{R_1^4 \sigma_{R_2}^2 + R_2^4 \sigma_{R_1}^2}{(R_1 + R_2)^4}}$
This equation tells us how to determine the equivalent resistance for a parallel combination of two resistors.	This is a "helper" equation – a tool to find the error on R_{eq}. The experiment was NOT designed around it.

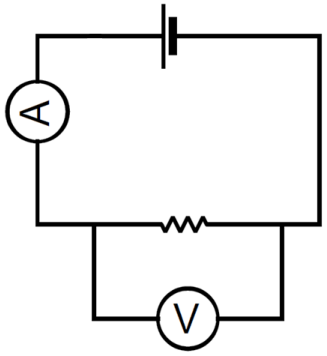
Apparatus

- Some one who wants to re-create your experiment, should be able to obtain specific information about the equipment you used
- List the equipment and include:
  - Manufacturer and Model #
    - Reading error and Range
      - Any other specifics you can find

The *only* place is your report where point-form is allowed

- **Must include all circuit diagrams** (when there is a circuit in the experiment)

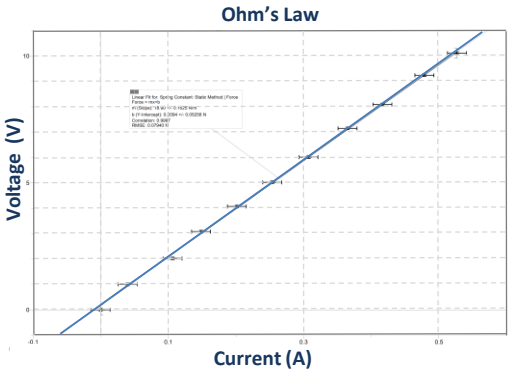
Do NOT waste your time drawing the components!

Include ✓	Don't include ✗
 The circuit diagram tells us how components must be connected. **IMPORTANT** (the experiment cannot be performed without correct connections)	 A sketch tells us what the component looked like. **IRRELEVANT** (a different looking component might have the same functionality)

Observations

- Combination of data tables from the manual and tables/graphs from Logger Pro
  - No need to re-create the Logger Pro information inside the Observations section. Sufficient to add a reference in the Observations to the tables/figures attached at the back of the report
- Make a neat copy of any hand-written tables
- **Watch for the correct number of significant figures!**
- Every table/graph/figure must have:
  - **Number**
    - **Caption**

A ***caption*** must be descriptive:
- Several sentences
- Everything there is to know about the graph/table
- Explain the reason for the graph/table's existence

Caption Example		
A graph	**Unacceptable** 	**Acceptable** 
	"V vs I" "Voltage vs Current" "Ohm's Law"	"The relationship between Voltage and Current. The graph was generated using data from Table 1 collected during the Ohm's Law part of the DC Circuits experiment. The slope of the graph represents the value of the resistance, R, for the circuit in question."

Calculations

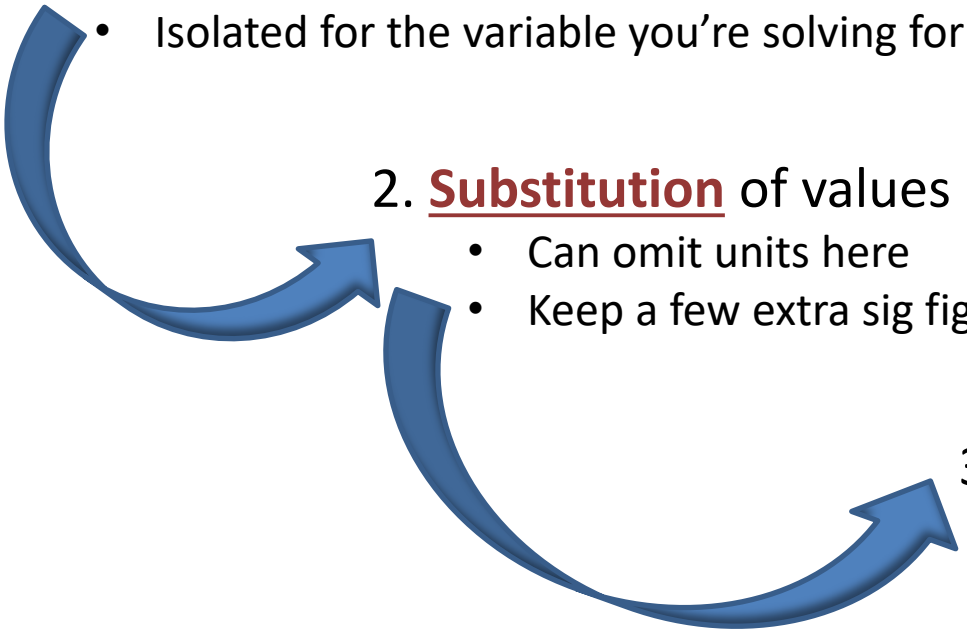
- Must show every calculation you did, unless otherwise specified
  - If the manual asked you to 'calculate' something – show it!

- Every calculation you show must be done in ***3 steps***:

1. **Equation** you're using
   - Isolated for the variable you're solving for

2. **Substitution** of values into the equation
   - Can omit units here
   - Keep a few extra sig figs

3. Numerical **Result**
   - Must have correct units



How to format calculations

Example

Calculation of the resistivity of wire:

Equation

$$\rho = \frac{\pi R d^2}{4L}$$

Substitution

$$\rho = \frac{(3.14)(9.05\ \Omega)(0.401 \times 10^{-3}\ \mathrm{m})^2}{4(115.66 \times 10^{-2}\ \mathrm{m})}$$

$$\rho = 9.88 \times 10^{-7}\ \Omega\mathrm{m}$$

Result

Calculation of the error on the resistivity of wire :

Note: *error calculation is treated separately!*

Equation

$$\sigma_\rho = \rho \sqrt{\frac{\sigma_R^2}{R^2} + \frac{2\sigma_d^2}{d^2} + \frac{\sigma_L^2}{L^2}}$$

Substitution

$$\sigma_\rho = (9.88 \times 10^{-7}\ \Omega\mathrm{m}) \sqrt{\left(\frac{0.02}{9.05}\right)^2 + 2\left(\frac{0.005 \times 10^{-3}}{0.401 \times 10^{-3}}\right)^2 + \left(\frac{0.11 \times 10^{-2}\ \mathrm{m}}{115.66 \times 10^{-2}}\right)^2}$$

$$\sigma_\rho = 1.76 \times 10^{-8}\ \Omega\mathrm{m}$$

Result

Therefore, the value of the resistivity of wire is:

$$\rho = (9.88 \times 10^{-7} \pm 1.8 \times 10^{-8})\ \Omega\mathrm{m}$$

$$\therefore \boldsymbol{\rho = (9.88 \pm 0.18) \times 10^{-7}\ \Omega\mathrm{m}}$$

Final result correctly reported

Results

- Only report the **main values**
  - What you said you were trying to find in the *Purpose* must be stated in *Results*
    - No need to include results to intermediate calculations
- If you performed a **consistency test**, comment on the agreement
  - Sometimes you compare two experimental values to each other, other times you'll be asked to compare your experimental value to a known theoretical one. Either way, you should state in the *Results* if the values are consistent or not.
- Proper formatting is expected:
  - **Significant Figures!!!**
    - **Units!!!**
- Don't forget that the error you calculated is part of the value you're reporting

How to report values

In physics, numerical results are always expressed as:

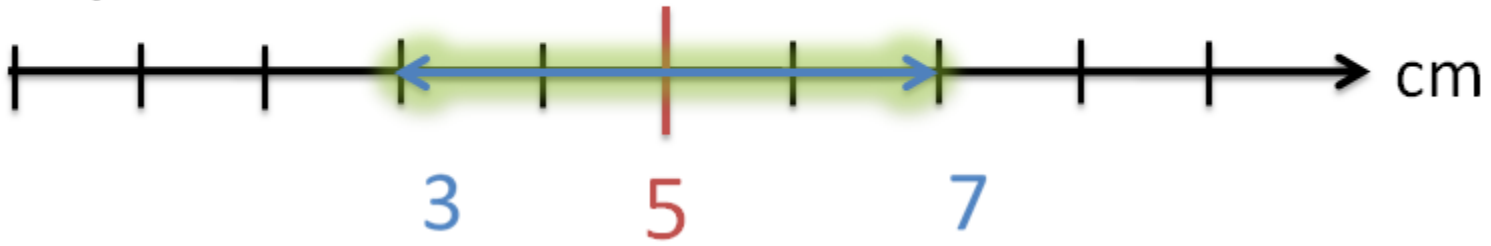
$$(m \pm \sigma_m)\ units$$

If using scientific notation, use same multiplier:

$$(m \pm \sigma_m) \times 10^n\ units$$

There is a 68% chance that the real value lies within $\pm\sigma_m$ of your measured value.

Example: (5 ± 2) cm



Discussion

Questions from Manual

- All questions in the Manual must be answered
- The **bulk** of the Discussion grade
- Will need to do a bit of research

~80%

Practical applications

- Any everyday applications of the physics principles involved
- Applications of equipment to other areas (not necessarily physics)

~5%

Discussion Grade

~10%

Sources of Error

- Random vs Systematic Errors
- How the results were influenced
- Assessment of experiment, consistency expectations, etc.

~5%

Possible Improvements

- Must be possible with the equipment provided
- "Buy new equipment" = unacceptable

Discussion: Sources of Error

- Identify quantities which contribute the most and the least to the overall error

Sources of Error ≠ Mistakes!

NOT a Source of Error:

- "Bad/old equipment"
  - ➢ If there was an issue with equipment, get a TA/Supervisor to verify it
  - ➢ If you want to comment on equipment – be specific, for example:
    - ✓ Non-zero wire resistance
    - ✓ Rust
    - ✓ Precision
- **Lab partner**
  - ➢ Stay professional and polite
- Calculation/Procedure mistakes
  - ➢ Sloppiness is not a source of error

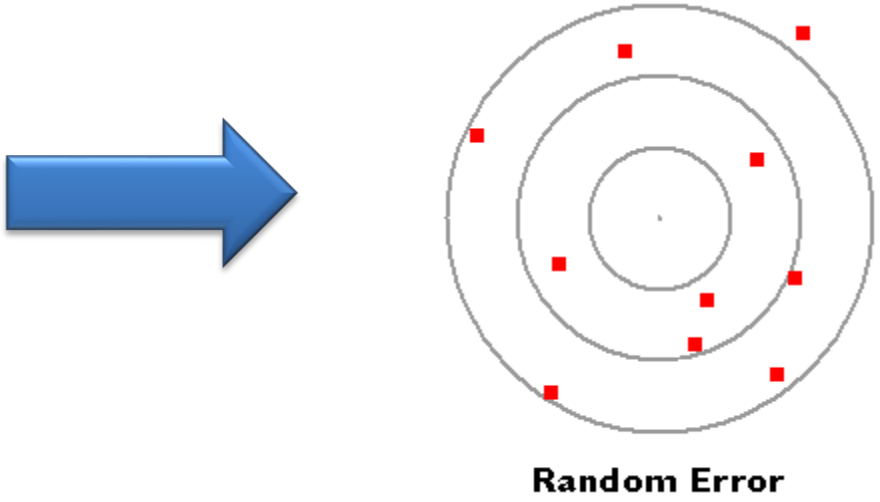
"HUMAN ERROR"

- **ZERO marks on *Discussion***
- AKA 'incompetence'
- Usually used as a blanket term for various mistakes – unacceptable
- Depending on situation, the experimenter's bias is a source of either random or systematic errors – must be able to distinguish them!

Discussion: Sources of Error

Random Errors:

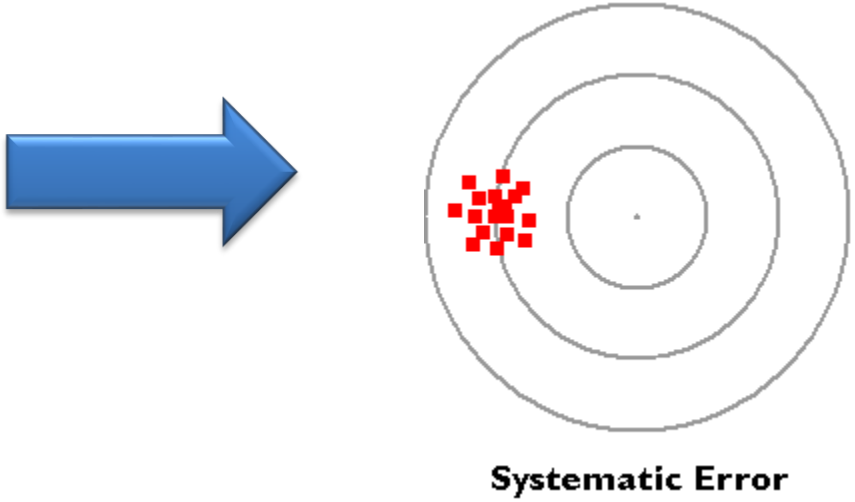
- unpredictable fluctuations in repeated measurements



Random Error

Systematic Errors:

- inherent attributes of the experimental method, procedure, apparatus



Systematic Error

https://www.e-education.psu.edu/natureofgeoinfo/c5_p5.html, 2012

Accuracy vs Precision

Precision

- how reproducible is the result
- affected by *random errors*

Not Accurate
Not Precise

Not Accurate
Precise

Accuracy

- how close is the result to a known value
- affected by *systematic errors*

Accurate
Not Precise

Accurate
Precise

Error: Numerical Value

- **Error, σ,** represents the precision of your measurements/results
  - i.e "how sure" you are about your results
  - does not have a negative meaning – it does not mean you have done something wrong
  - "**Error**" and "**uncertainty**" are used interchangeably

Two main types

Reading Error (RE)

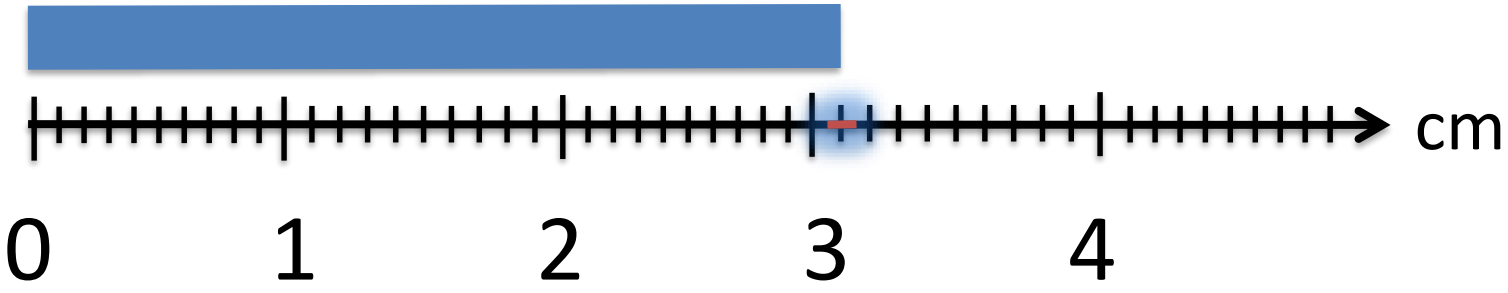
- Obtained directly from equipment
- **1 sig fig**

Propagated Error (PE)

- Obtained through additional calculations
- Can be Statistical Error (SE) or determined using error propagation equations
- **2 sig figs**

Reading Error

Analog: ½ × (Value of the smallest division)



(3.10 ± 0.05) cm

Reading Error

Digital: 2 × (Value of the smallest division)

(273.3 ± 0.2) mV

Statistical Error (SE)

- When measurements of the same quantity vary, there's an uncertainty due to this variation.
  - For $\boldsymbol{N}$ data values, the standard deviation ($\boldsymbol{\sigma_{SD}}$) is a measure of the dispersion of these values.
  - Statistical error is the **standard deviation of the mean,** $\boldsymbol{\sigma_{mean}}$ (sometimes called "standard error"):

$$\boldsymbol{\sigma_{mean} = \frac{\sigma_{SD}}{\sqrt{N}}}$$

Number of Significant Figures

STEP 1:

Look at the error:

- Propagated/statistical error → round to 2 sig. figs.
- Reading error → round to 1 sig. fig.

STEP 2:

Look at the value:

- Make sure your value (measurement/result) has the same number of decimal places as the error. The value cannot be more/less precise than the error.

Section C* (C.9 pg. 12-13) of *General Information

Examples

Assuming the quoted errors are either statistical or propagated
we round the error to 2 sig figs.

(12.32351 ± 0.3127) mm → (12.32 ± 0.31) mm

(99.235 ± 0.102) g → (99.24 ± 0.10) g

(16.99342 ± 2.14) V → (17.0 ± 2.1) V

(0.035 ± 0.052) mm → (0.035 ± 0.052) mm

$53.33 \times 10^{-9} \pm 2.315 \times 10^{-10}$ m → $(5.333 \pm 0.023) \times 10^{-8}$ m

Note: Significant Figures are NOT the same as decimal digits.