**PHYS170L-003: Lab Report Guide**

Student's Name — Date: August 28, 2018
Names of Partner(s)

1. **Abstract**
   - Big picture summary of the physics principle(s) explored in the lab (one or two sentences).
   - Brief description of the experimental setup, the variables, and the data/measurements actually collected (two to three sentences).
   - Summary of the student's results with the ranges of actual numbers (e.g., means, experimental values) in comparison with the expected/theoretical values (two to four sentences).
   - Statement(s) about whether the students' results were accurate and precise or not, with quantified evidence (e.g., $\mathcal{N}_s$ and fractional error or percent error, discussed below).
   - *Assessment:* Would a science-literate person who knows nothing about the experiment understand:
     (a) why the experiment was done?
     (b) what was done?
     (c) what the results were?
     (d) what was concluded?

2. **Introduction**
   - More details on the big picture of the physics principle(s) relavant to the experiment.
   - All in the student's own words.
   - *Assessment:*
     (a) Does the student show s/he understands the physics background and motivation?
     (b) Are the important equations derived or at least introduced?
     (c) Are the variables defined? (See the Statistics Interlude below for how variables are introduced.)
     (d) Is it clear what will be expected/theoretical values and what will be experimental?

3. **Procedure**
   - Explanation if the implemented procedure deviated from the lab manual. Otherwise, explicitly refer the reader to the provided lab manual.
   - All in the student's own words.
   - *Assessment:*
     (a) Are the deviations in procedure from the posted lab manual clearly explained? Or is it explicitly stated that the procedure followed the provided lab manual?

4. **Raw Data**
   - Present all data recorded during the experiment, typically in a well-organized table with informative headers, appropriate units, and uncertainties, if applicable.
   - The Raw Data table may include Derived Data columns (described in the next section) so as not to needlessly duplicate.
   - *Assessment:*
     (a) Is the table clearly labeled with informative headers and units?
     (b) Is the information consistent with what was discussed in the Introduction and, as applicable, Procedure sections?
     (c) Do the raw data agree with the partner's?

**5. Derived Data, Calculations, and Error Analysis**

- Presentation of one complete example calculation or description of what software and which of its formula/functions were used to perform the calculations.
- For multiple measurements of the same quantity: calculation/presentation of the mean and sample standard deviation.
  - *Statistics interlude:*
    - The mean (AKA average) is calculated as $\bar{x} = \frac{1}{\mathcal{N}}\sum_{i=1}^{\mathcal{N}} x_i$, where $\mathcal{N}$ is the total number of measurements, $x_i$, that are summed (that is the $\sum_{i=1}^{\mathcal{N}}$ notation). It has the same units as $x_i$.
      - Note: it does not have to be $x_i$ and $\bar{x}$. The notation should be sensible and informative. For example, if one were measuring velocity, it would be more informative to use $v_i$ for the individual measurements and $\bar{v}$ for the mean.
    - The *sample* standard deviation is calculated as $s = \sqrt{\frac{1}{\mathcal{N}-1}\sum_{i=1}^{\mathcal{N}}(x_i - \bar{x})^2}$. It has the same units as $x_i$ and $\bar{x}$.
    - The *sample* standard deviation is different from the *population* standard deviation (which is divided by just $\mathcal{N}$ and not $\mathcal{N} - 1$). It is the responsibility of the student to verify whatever software formula s/he uses to compute the "standard deviation" returns the *sample* standard deviation.
      - Note: By convention, *population* mean is denoted $\mu$ ("mu"), and the population standard deviation is $\sigma$ ("sigma"). "Population" refers to the absolute truth, which we try to measure but usually we cannot make the measurements of everything nor conduct infinite trials. Scientific literature is sometimes sloppy and will use $\mu$ and $\sigma$ for *sample* mean and standard deviation.
    - The mean, $\bar{x}$, and sample standard deviation, $s$, are measured from the experimental data. Thus, assuming Gaussian statistics, roughly 68.3% of the experimental measurements should fall within $\bar{x} - s$ and $\bar{x} + s$ (AKA $\bar{x} \pm s$); roughly 95.4% should fall within $\bar{x} \pm 2s$; and roughly 99.7% within $\bar{x} \pm 3s$. Therefore it is *not* useful to compare the dispersion (i.e., spread) of the experimental measurements (e.g., quoting the minimum and maximum values) with the experimental mean, $\bar{x}$, and its sample standard deviation, $s$.
    - It *is* useful to compare the experimental mean with the expected or theoretical value, $x_{\text{theor}}$. It is also appropriate to use the experimental sample standard deviation to quantify accuracy and precision, detailed below.
- Assess accuracy and precision:
  - "Accurate" is typically defined as $\mathcal{N}_s = \left|\frac{x_{\text{theor}} - \bar{x}}{s}\right| \leq 3$, which means in 99.7% of the experiments, the experimental mean is within $\pm 3s$ of the expected/theoretical value, $x_{\text{theo}}r$.
  - "Precise" generally means $\frac{s}{|\bar{x}|} \times 100\% \lesssim 10\%$.
  - If there were no standard deviation, the results are assessed to be accurate if the percent error is $\left|\frac{x_{\text{theor}} - \bar{x}}{x_{\text{theor}}}\right| \times 100\% \lesssim 10\%$. And if there is no sample mean, $\bar{x}$, compare $x_{\text{theor}}$ with individual measurements $x_i$.

- Discussion of converting and/or canceling units, as appropriate.
- *Assessment:*
  (a) Is there an example calculation with appropriate units shown? If not, was the software procedure adequately described?
  (b) Is the derived results presented clearly with appropriate/reasonable significant figures?
  (c) Are the expected/theoretical results presented along with the derived results?
  (d) Is it clear what the units are?

**6. Conclusion**

- Brief re-statement of the big picture physics background and the specific purpose of the experiment.
- Brief re-summary of what was done (e.g., what data were collected).
- Synthesis of the experimental and theoretical results, which includes summarizing the results (numerically).
- Comments on accuracy and precision.
- Discussion of what was actually learned, in particular what might have caused errors if the experiment did not convincingly show the physical phenomenon.
- *Assessment:*
  (a) Does the Conclusion demonstrate that the student thought about the experiment and its purpose?
  (b) Is the Conclusion consistent with the evidence?

**7. References**

- If any sources besides the lab manuals, videos, or course textbook were used, they are cited here. Citing a work does not mean it can be plagiarized.
- *Assessment:*
  (a) Does this section exist? Even with "None" or "N/A" only.
  (b) If some of the writing seems suspicious (i.e., plagiarized) and an internet search confirms some significant overlap, is that source cited here?

General requirements:

- The whole report should be typed (unless writing-in equations) and in one document.
- Physical quantities nearly always have units, and the units should always be provided.
- It should be written in the past tense, unless stating a fact that is true beyond the scope of the report (e.g., "Newton's second law is $F = ma$.")
- The subject should be "we" when it applies to all partners and "I" when it is important to highlight what the author of the report did. Science papers are always first person plural (e.g., "we did"), third person (e.g., "the authors did"), or passive voice (e.g., "it was done"). The lab reports should only use first person plural (e.g., "we did") or passive voice (e.g., "it was done").
- This is formal writing, so there are no contractions (e.g., use "do not" instead of "don't").
- The report is reasonably well-written, meaning it was spell-checked and read through aloud to polish the most awkward sentences.
- The word "data" is plural (e.g., "data were recorded") and "datum" is singular (e.g., "datum was recorded").