PHY 133 Studio Lab Report Format

Laboratory experiments are an essential component of learning physics. The laboratory grade will be based upon participation and successful completion of ten experiments. As part of your grade for PHY 133, you are required to complete three formal lab reports. Writing the lab report communicates what you have accomplished during the lab and how well you have understood the physics concepts and empirical data. You need to organize and present your work accurately and concisely using scientific writing. All lab reports should have the following features:

- The lab report should be concise but should also contain the necessary details and well-developed explanations.
- The lab report should be organized with appropriate headings and subheadings.
- The lab report should contain all the relevant information and reasoning. The information you present should validate your conclusions.

Lab reports should contain the following components, as appropriate:

- **Abstract.** The purpose and hypothesis of the experiment should be correctly formulated. State what you were trying to accomplish. Link lab concepts to physics theories learned in class. Provide the names of your lab partners and date when lab was performed.
- **Procedure.** Briefly outline the methodology. The procedure should be clear and reproducible. This section should demonstrate your understanding of what you measured and how you measured it.
- **Materials.** Provide descriptive details on the materials and apparatus used to collect data.
- **Data and Calculations.** Include the raw data you collected and an estimate of the error for all measured values. Present data in an organized manner (e.g., tables) and include correct units. There should be a sufficient number and range of data values. Provide sample calculations with correct equations and number of significant figures.
- **Graphs.** Include graphical representations of data. Graph titles should be descriptive and axes labeled with values and correct units. Regression formula should be on the graph with correct units, indicating the significance of the slope and y-intercept. Computer-generated graphs with the online plotting tool are sufficient.
- **Error Analysis.** You cannot draw any final conclusions from your data without considering how well you can trust your data and what factors may have affected it. Also, you often need to propagate your error from measurements through calculations and graphs. Error analysis should consider multiple sources of error, should demonstrate a strong understanding of uncertainty techniques, and should be consistent with the magnitude and direction of the error. Refer to the *Guide to Estimating Uncertainty* posted on Blackboard.
- **Results and Conclusions.** Interpret your results and answer the question or provide reasons for supporting/rejecting the hypotheses stated in the abstract. Clearly explain your results and discuss potential sources of error in your experimental design. Compare your results to theoretical values (e.g., acceleration due to gravity on Earth) by reporting percent error. Provide recommendations for future experiments to improve results.
- **Questions.** Provide thoughtful answers to questions posed at the end of each lab procedure, incorporating physics concepts in your rationale. Note: There were no questions for Lab 2 on projectile motion. If you write you report on this lab you should instead include a copy of the graph you made by hand as well as the computer generated plot and comment on differences between the two graphs and the values obtained from them.
The following sample lab report provides a guide for general expectations, using the *Acceleration Due to Gravity Lab* performed during Week 1.

**Lab Report – Acceleration Due to Gravity**  
August 27, 2014  
John Smith

Lab Partners: Jane Jones, Amanda Johnson

**Abstract**

The purpose of the experiment is to measure the acceleration due to gravity \( g \) by collecting displacement and velocity data over equal time intervals for a freely falling object. It is hypothesized that the acceleration of the picket fence in this experiment will encounter minimal drag force, and the measured value of the acceleration will be consistent with the accepted value of 9.81 m/s\(^2\).

**Procedure**

In each trial, a picket fence was dropped through a photogate to measure the acceleration due to gravity experimentally. Six trials were conducted in the following manner:

1. The photogate was connected in the digital channel port of the LabQuest.
2. The LabQuest modes were set to “photogate timing,” “motion,” “Vernier picket fence,” and “end data collection.”
3. The collect data arrow was clicked before the picket fence was released from approximately 2 cm above the photogate beam. The picket fence did not touch the photogate.
4. The distance vs. time graph was checked for at least 7 measured values.
5. The velocity vs. time graph was analyzed with the LabQuest by selecting “analyze,” “curve fit,” and “linear.” The values for slope and y-intercept were recorded.

**Materials**

The materials for this lab included the following:

- Vernier LabQuest interface device to collect and graph displacement and velocity data.
- Photogate for accurate timing of event, with attached rod and connecting cable to LabQuest.
- Stand and clamp to support photogate.
- Picket fence with 8 opaque bars spaced every 5 cm to block the infrared beam from the photogate.

**Data and Calculations**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Slope (m/s(^2))</th>
<th>y-Intercept (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.76</td>
<td>0.14</td>
</tr>
<tr>
<td>2</td>
<td>9.80</td>
<td>0.12</td>
</tr>
<tr>
<td>3</td>
<td>9.65</td>
<td>0.12</td>
</tr>
<tr>
<td>4</td>
<td>9.66</td>
<td>0.10</td>
</tr>
<tr>
<td>5</td>
<td>9.72</td>
<td>0.20</td>
</tr>
<tr>
<td>6</td>
<td>9.76</td>
<td>0.15</td>
</tr>
</tbody>
</table>
The average value of the slope is

\[
\bar{g} = \frac{9.76 + 9.80 + 9.65 + 9.66 + 9.72 + 9.76}{6} = 9.725 \text{ ms}^{-2}
\]

**Graphs**

The following graph sketches represent displacement vs. time, velocity vs. time, and acceleration vs. time for the picket fence falling under the influence of gravity. The downward motion is represented in the positive reference frame.

**Error Analysis**

From the six values of slopes, the average and absolute error in the average were calculated using equations E.5 and E.5b from the *Guide to Estimating Uncertainty*.

The average value of the slope, calculated from equation E.5, is

\[
\bar{g} = \frac{9.76 + 9.80 + 9.65 + 9.66 + 9.72 + 9.76}{6} = 9.725 \text{ ms}^{-2}
\]

The absolute uncertainty in this value, calculated from equation E.5b, is

\[
\Delta \bar{g} = \sqrt{\frac{\sum_{i=1}^{6} (g_i - \bar{g})^2}{6 \times 5}}
\]

\[
\]

\[
= 0.025 \text{ ms}^{-2}
\]

**Results and Conclusions**

The measured value of \( g \) in our experiment was \( g = 9.725 \pm 0.025 \text{ ms}^{-2} \). While this value is close to the accepted value of 9.81 m/s\(^2\), the accepted value does not lie within our estimate of the random error of our experiment, and so our experiment is not consistent with our expectation.

The discrepancy may be due to a number of factors. We have neglected drag forces and these would be expected to reduce the acceleration from that expected in the drag free cases. We have also not considered sources of systematic errors that may affect our experiment. One possible
source of error could be that the spacing between pickets in the fence may not correspond exactly to the value stored in the LabQuest apparatus. While it does not seem likely that the painted pickets are inaccurate, if the picket fence was not dropped completely straight, the apparent spacing of the pickets would be smaller than the actual spacing, which might affect the measured displacement versus time.

The experiment could potentially be improved by replacing the manual drop of the ruler by a mechanical release that could ensure the ruler is dropped completely straight.

**Questions**

1. The experimental value of the acceleration due to gravity does not depend on the mass of the object. This concept could be tested by dropping a similar object of different mass through the photogate and finding the slope of the velocity vs. time graph. Similarly, marbles of different masses could be rolled from rest down an inclined plane and timed. Galileo used this procedure to *disprove* the notion that objects of different masses accelerate at different rates due to gravitational force.

2. If the picket fence had an initial downward velocity:
   a. The acceleration due to gravity would still be the same as the one recorded earlier. Once the applied force ceases and the object is only under the influence of gravity, it is in a state of free fall and experiences an acceleration of 9.81 m/s$^2$.
   b. The velocity vs. time graph would still be linear, but the y-intercept would have a value other than zero, representing the initial velocity, as shown below. The slope of the graph would still be equal to the acceleration due to gravity. The graph below represents an initial downward velocity in the positive reference frame.

   ![Graph](image)

   The graph below represents a velocity vs. time graph for an object released from rest with downward velocity in the positive reference frame.

3. If the picket fence had an initial upward velocity:
   a. The acceleration due to gravity would still be the same as the one recorded earlier. Once the applied force ceases and the object is only under the influence of gravity, it is in a state of free fall and experiences an acceleration of 9.81 m/s$^2$. 

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b. The velocity vs. time graph would still be linear, but the y-intercept would have a value other than zero, representing the initial velocity as the picket fence passes through the photogate, as shown below. The slope of the graph would still be equal to the acceleration due to gravity. The graph below represents the downward velocity the picket fences experiences as it passes through the photogate in the positive reference frame.

![Graph 1](image1.png)

The graph below represents a velocity vs. time graph for an object released from rest with upward velocity. The downward velocity as the object passes through the photogate is represented in the positive reference frame.

![Graph 2](image2.png)
# PHY 133 Studio Lab Report Grading Rubric

<table>
<thead>
<tr>
<th></th>
<th>Exceeds Expectations (4)</th>
<th>Meets Expectations (3)</th>
<th>Expectations Not Met (1-2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>Credibly links lab concepts to physics principles.</td>
<td>Purpose and hypotheses are correctly formulated. Objectives(s) of lab are clearly articulated.</td>
<td>One or more of the expected components is missing or incorrect.</td>
</tr>
<tr>
<td><strong>Methods/ Materials</strong></td>
<td>Methodology is clearly described and reproducible. Apparatus is detailed and descriptive.</td>
<td>Apparatus and materials are listed. Procedure is reasonably well described.</td>
<td>Procedure is confusing or incomplete.</td>
</tr>
<tr>
<td><strong>Data/Results</strong></td>
<td>Explanations are provided for all tables and graphs. Measuring devices are indicated. Titles are descriptive and meaningful. There are no errors in data collection.</td>
<td>Data is well organized with appropriate units and uncertainties. Graphs are properly constructed with title, axes labels, and line of best fit where appropriate. Regression formula is given. Results are reasonably accurate. There are a sufficient number and range of data values.</td>
<td>Data is absent or misrepresented. Tables and graphs are missing titles, headings, units, or uncertainties. The reader has difficulty ascertaining where the numbers came from. Multiple errors are cited.</td>
</tr>
<tr>
<td><strong>Calculations/ Error Analysis</strong></td>
<td>Results are interpreted, not just restated. Relationships between variables are analyzed. Error analysis considers multiple sources of error, demonstrating a strong understanding of techniques. Error analysis is consistent with data in terms of magnitude and direction of error. There are no errors in calculations.</td>
<td>Reasonable uncertainty estimates are given for instruments and procedures. Sample calculations utilize appropriate equations, with correct substitutions, units, and precision (significant figures). There may be one or two errors in calculations or data.</td>
<td>Discussion and interpretation of results is weak, with few references to data, graphs, and results. Important sources of error are omitted.</td>
</tr>
<tr>
<td><strong>Conclusions/ Lab Question</strong></td>
<td>A rationale is given for supporting or rejecting the hypothesis or achieving the purpose of the lab. Interpretation of results is clearly explained. There is a clear assessment of whether the experimental design adequately addressed the hypothesis. Recommendations for future experiments are understandable and well thought out. Lab questions are answered completely and accurately.</td>
<td>Brief conclusions summarize whether the purpose was achieved, lessons learned, and suggested improvements. Lab questions are addressed.</td>
<td>Conclusions do not draw logically from results. Suggestions for lab improvements are weak. Purpose or hypothesis is not adequately addressed. Lab questions are unanswered or contain errors.</td>
</tr>
</tbody>
</table>