Lab Report Suggestions: Phy191 Spring 1999

The lab report that each group will submit (by the end of the second week of each experiment) consists of the following sections: Purpose and Procedures, Data Summary, Sample Calculations, Results and Conclusions and Discussions. The following is an outline of a lab report that includes *instructions* as well as an **example** of an experiment. **Note: Example given in this template is not meant to be complete. It does not suggest the length of the report, since the length of your report will solely depend on the content and the subject of the experiment.**

Purpose and Procedures:

In the purpose section you state or describe in your own words the objectives of the lab. You should specifically state what principles or laws of physics you will be investigating and your experimental approach.

Example: In this experiment we study the motion of a projectile in two dimensions. Using kinematics and Newton's second law of motion, we calculate the acceleration due to gravity and compare it to the accepted value, g = 9.810 m/s^2.

Data Summary:

In this section you briefly describe how data are collected and show examples. Keep in mind that this should be a representative sampling only, since you will use them as a reference for later discussion of analysis. Typically the data are entered in K-graph, or in Excel, which allows you to do all the necessary manipulations/calculations with the data. You should state the estimated uncertainties for all relevant measurements. Check all values for the correct number of significant figures.

Example: We acquired our data points from a computer generated-movie running in real time with 30 frames per second. Therefore the time between images is 0.033 second. The velocity of a projectile is a vector, $\vec{v}$, tangent to the flight path. This vector can be decomposed into x and y components. Both x and y data points are then used to calculate the x and y components of the (average) velocity using formulae described in the lab manual which are included in the next section. Some of these data are listed in the Table 1.1.

Table 1.1

Dot	time(t)	X(i)	Y(i)	Δt	ΔX(i)	ΔY(i)	$V_x(i)$	$V_y(i)$
i	[s]	[m]	[m]	[s]	[m]	[m]	[m/s]	[m/s]
1	4.970	0.240	0.370					
2	5.000	0.290	0.510	0.060	0.100	0.280	1.667	4.667
3	5.030	0.340	0.650	0.070	0.050	0.140	0.714	2.000
4	5.070	0.380	0.760	0.070	0.040	0.110	0.571	1.571
5	5.100	0.427	0.872	0.063	0.047	0.112	0.746	1.778
6	5.133	0.470	0.976					

This table was prepared using Excel. It can be imported into Microsoft Word using the ordinary copy and paste procedure.

For each measured x_i and y_i we assigned an error based on how precisely we measured that particular point. The estimated uncertainties for x and y coordinates are:

$$\delta x = \pm 0.002 \textbf{ m}$$
$$\delta y = \pm 0.003 \textbf{ m.}$$

Sample Calculations:

The Sample Calculations section consists of a discussion on how your data are manipulated. You show how the data are used to find physical constants. Describe any conversions you have performed in your calculation; they should be in standard units. For instance, the unit of your calculated/measured velocity should be in meters per second, [m/s], etc.

Example: We calculated our x- and y-component of the velocity using the following formulae:

$$\mathrm{v_x}(i) = \Delta\,\mathrm{x}(i) / \Delta\,\mathrm{t}\,, \quad \Delta\,\mathrm{x}(i) = \mathrm{x}(i+1) - \mathrm{x}(i-1)$$
$$\Delta\,\mathrm{t}(i) = \mathrm{t}(i+1) - \mathrm{t}(i-1)\,,$$

and similarly for *y*. Note that according to the above formulae, the velocity at the first point cannot be calculated; hence no entry for the first and last row for the velocity as is evident in the Data Summary section. These are calculated as follows:

$$\mathrm{v}_y(2) = \frac{y(3) - y(1)}{t(3) - t(1)} = \frac{0.650m - 0.370m}{5.030s - 4.970s} = 4.67 \textbf{ m/s.}$$

The above equations were prepared using the Word Equation Editor. This editor can be activated via the Insert pull-down menu, then choose Object; then Equation.

To estimate the acceleration due to gravity, we plot v_x vs. t and v_y vs. t using *K-graph*, and perform the least squares fit procedure to determine the slope, which then yields the value for *g*. We curve fit our data using a linear function $v_y = v_{y0} - gt$ which has the form $y = A + Bt$.

In calculating the errors for our x- and y-components of the velocity, we assume that the error in the time interval is negligible. Therefore, the error in the speed at each point is

$$\delta\,\mathrm{v_y} = \mathrm{v}_y\sqrt{\left(\frac{\delta(\Delta y)}{\Delta y}\right)^2 + \left(\frac{\delta(\Delta t)}{\Delta t}\right)^2} = \mathrm{v}_y\,\frac{\delta(\Delta y)}{\Delta y} = \frac{2\,\mathrm{v_y}\,\delta y}{\Delta y}\,,$$

where $\delta(\Delta y) = 2\delta y$. The same formula is also valid for the x component. Based on this formula, the error in the speed (in the y component) at *i* = 2 can be calculated as follows:

$$\delta \mathrm{v}_y = \mathrm{v}_y \frac{2\delta y}{\Delta y} = (4.67\ \mathbf{m/s}) \frac{0.006m}{0.280m} = 0.10\ \mathbf{m/s.}$$

Therefore,

$$\mathrm{v}_y(2) = 4.67 \pm 0.10\ \mathbf{m/s.}$$

The uncertainty for the acceleration due to gravity, g, can be estimated by using the following procedure. Recall that our g value is determined by applying the least-squares fitting to our data (a total of 20 points): $\mathrm{v}_y = \mathrm{v}_0 - gt$ **.**

The following formulae [cf. Taylor, Chapter 8] will be employed to estimate the error in g:

$$\sigma_{\mathrm{g}} = \sigma_{\mathrm{V_y}} \sqrt{\frac{N}{\Delta}}, \quad \Delta = N \sum_{i=1}^{N} t_i^2 - \left(\sum t_i\right)^2$$

$$\sigma_{\mathrm{V_y}} = \sqrt{\frac{1}{N-2} \sum_{i=1}^{N} \left(\mathrm{v_i} - \mathrm{v}_0 + g t_i\right)^2}\ .$$

Thus,

$$\Delta = N \sum_{i=1}^{N} t_i^2 - \left(\sum t_i\right)^2 = 15.33$$

$$\sigma_{\mathrm{V_y}} = 0.194$$

$$\sigma_{\mathrm{g}} = \sigma_{\mathrm{V_y}} \sqrt{\tfrac{N}{\Delta}} = 0.22$$

where D is in [s^2], $\sigma_{\mathrm{V_y}}$ [m/s] and σ_{g} [m/s^2]. Therefore, the error in g is 0.22 m/s^2. The uncertainty for the slope of v_x (the acceleration in the x-direction) can be found in the same way, and its value is 0.17 m/s^2.

Results:

This section is probably one of the important sections in your lab report. In here you describe the analysis of your data and your findings. Discuss the meaning of your results and the role of statistical (random) and systematic errors. Include any graphs that illustrate curve fitting and the resulting parameters.

Example: The slope of v_y given by *K-graph*, which is the g value, is 9.612 m/s^2 as illustrated in Fig. 1. Therefore, our value for g, including the uncertainty is

$$\mathrm{g} = 9.612 \pm 0.22\ \mathbf{m/s^2.}$$

This result is in good agreement with the expected value g = 9.810 m/s^2. The slope of v_x with its estimated uncertainty is

$$a_x = 0.310 \pm 0.17 \, \mathbf{m/s^2}.$$

In our analysis the two-dimensional motion is decomposed into a horizontal component, v_x, and a vertical component v_y. So we have motion with constant velocity (which implies no acceleration) in the horizontal direction. Our slope of 0.310 ± 0.17 m/s^2 for this component is reasonable, even though it should come very close to 0 m/s^2. This slight variation suggests that random and systematic error may be involved. We speculate that our random error is due to our inaccuracy in controlling the video-point when following the projectile's path, especially the horizontal component, while systematic error may occur during a conversion from pixels to meters.

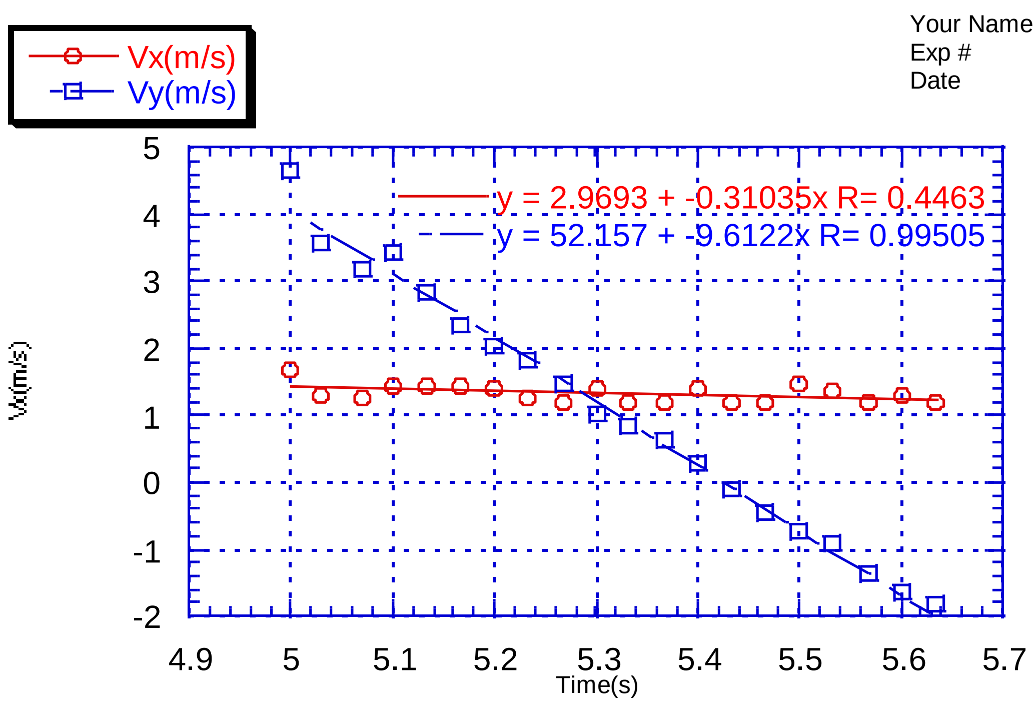

Fig. 1. A plot of v_x and v_y vs. time for a projectile.

This graph was prepared using K-graph. It was imported into Microsoft Word by using the usual copy and paste procedure.

Conclusions and Discussion:

In this section describe in your own words what you have observed. What statements can you make regarding the significance of the experiment? Answer all questions in the lab write-up. If your experiment involved measuring a physical constant and your results differ from the accepted (or expected) values, can you suggest why? List any questions that asked your instructors. What were the answers?

NOTE: For your lab report we recommend that you use Microsoft Word.