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Internal Laboratory Reports

Unit: Laboratory & Measurement

NGSS Standards/MA Curriculum Frameworks (2016): SP3, SP8

AP® Physics 1 Learning Objectives/Essential Knowledge (2024): SP3.C

Success Criteria:

- The report has the correct sections in the correct order.
- Each section contains the appropriate information.

Language Objectives:

- Understand and be able to describe the sections of an internal laboratory report, and which information goes in each section.
- Write an internal laboratory report with the correct information in each section.

Tier 2 Vocabulary: N/A

Notes:

An internal laboratory report is written for co-workers, your boss, and other people in the company or research facility that you work for. It is usually a company confidential document that is shared internally, but not shared outside the company or facility.

Every lab you work in, whether in high school, college, research, or industry, will have its own internal report format. It is much more important to understand what *kinds* of information you need to report and what you will use it for than it is to get attached to any one format.

Most of the write-ups you will be required to do this year will be internal write-ups, as described in this section. The format we will use is based on the outline of the actual experiment.

AP®

Although lab reports are not specifically required for AP® Physics, each section of the internal laboratory report format described here is presented in a way that can be used directly in the experimental design question.

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Title & Date

Each experiment should have the title and date the experiment was performed written at the top. The title should be a descriptive sentence fragment (usually without a verb) that gives some information about the purpose of the experiment.

Objective

This should be a one or two-sentence description of what you are trying to determine or calculate by performing the experiment.

Use this space for summary and/or additional notes:

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Experimental Design

This is the most important section in your report. This section needs to explain:

- What you were trying to observe or measure.
- If "actions" needed to happen in order to perform the experiment, how you made them happen. A flow chart can be useful for this
- Which aspects of the outcome you needed to observe or measure. (Note that you do not need to include the details of how to make the observations or measurements. That information will be included later in your procedure.)

Qualitative Experiments

If you are trying to cause something to happen, observe whether or not something happens, or determine the conditions under which something happens, you are probably performing a qualitative experiment. Your experimental design section needs to explain:

- What you are trying to observe or measure.
- If something needs to happen, what "actions" you will perform to try make it happen.
- How you will determine whether or not the thing you are trying to observe has happened.
- How you will interpret your results.

Interpreting results is usually the challenging part. For example, in atomic & particle physics (as well as in chemistry), what "happens" involves atoms and electrons that are too small to see. You might detect radioactive decay by using a Geiger counter to detect the charged particles that are emitted.

As you define your experiment, you will need to pay attention to:

- Which conditions you needed to keep constant (control variables)
- Which conditions you changed intentionally (manipulated variables)
- Which outcomes you observed or measured as a result of the "actions" (responding variables)

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Quantitative Experiments

If you are trying to determine the extent to which something happens, your experiment almost certainly involves measurements and calculations. Your experimental design section needs to explain:

- Your approach to solving the problem and/or gathering the data that you need.
- The specific quantities that you are going to vary (your manipulated variables).
- The specific quantities that you are going to keep constant (your control variables).
- The specific quantities that you are going to measure or observe (your responding variables) .
- How you are going to calculate or interpret your results.

One way to record this is to use a table like the one described in the Designing & Performing Experiments section (starting on page 36). Recall that the experimental design table from the sample experiment in that section looked like the following:

Desired Quantity	Equation	Description/ Explanation	Known Quantities	Quantities that Can be Measured	Quantities that Need to be Calculated
$\vec{F}_f$	$\vec{F}_f = \vec{F}_{net}$	Set up experiment so other forces cancel	—	—	$\vec{F}_{net}$
$\vec{F}_{net}$	$\vec{F}_{net} = m\vec{a}$	Newton's 2nd Law	—	m	$\vec{a}$
$\vec{a}$	$\vec{v} - \vec{v}_o = \vec{a}t$	Kinematic equation #2	$\vec{v}$	t	$\vec{v}_o$
$\vec{v}_o$	$\frac{\vec{d}}{t} = \frac{\vec{v}_o + \vec{v}}{2}$	Kinematic equation #1	$\vec{v}$	$\vec{d}$, t	—

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You can include this table directly in the write-up, along with information about each variable. Again, using the earlier example:

Actions (what needs to happen in the experiment):

The object needed to slide from a starting point until it stops on its own due to friction.

Known Quantities:

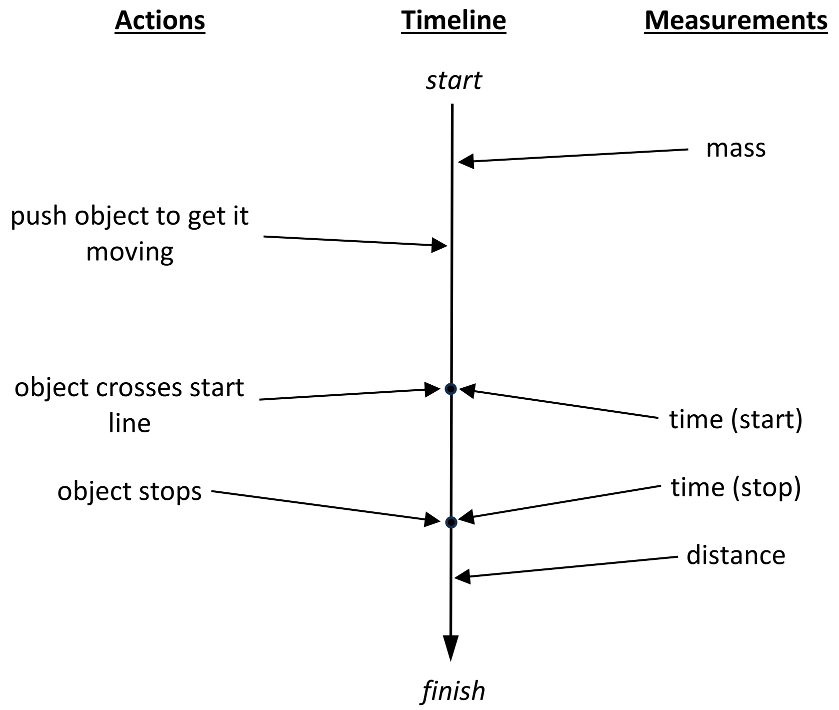
- constants: none
- control variables that do not need to be measured: final velocity $\vec{v} = 0$

Measured Quantities:

- control variables that need to be measured: mass (*m*) using a balance
- manipulated (independent) variables: none
- responding (dependent) variables: time (*t*) using a stopwatch; distance (*d*) using a meter stick or tape measure

Flow Chart:

In the flow chart, note that actions are on one side and measurements are on the other. Do not include anything else in the flow chart.



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The purpose of the flow chart when you designed the experiment was to show you what you needed to do in a visual, easy-to-follow manner. The flow chart serves the same purpose when you write up the experiment. The procedure starts at the top ("*start*" on the timeline) and ends at the bottom ("*finish*" on the timeline), which means you write the procedure starting at the top and moving down the timeline, describing each action and/or measurement in order from top to bottom.

Note that including your flow chart ensures that your reader understands the flow of the entire experiment from start to finish. This may be helpful in clarifying steps that you describe in your procedure.

Procedure

Your procedure is a detailed description of everything you did in the experiment. Because you have already included a flow chart, your procedure can be fairly brief and much easier to write. This section is where you give a detailed description of everything you need to do in order to take those data.

You need to include:

- A photograph or sketch of your apparatus, with *each component labeled* (with *both* dimensions *and* specifications), and details about how the components were connected. You need to do this even if the experiment is simple. The picture will serve to answer many questions about how you set up the experiment and most of the key equipment you used.
- A list of any significant equipment that is not labeled in your sketch or photograph. (You do not need to mention generic items like pencils and paper.)
- A narrative description of how you set up the experiment, referring to your sketch or photograph. Generic lab safety procedures and protective equipment may be assumed, but mention any unusual precautions that you needed to take.
- A narrative description of the "*actions*" in your experiment—everything you did to cause data to be generated.
- A descriptive list of your *control variables*, including their *values* and how you ensured that they remain constant.
- A descriptive list of your *manipulated variables*, including their *values* and how you set them.
- A descriptive list of your *responding variables* and a step-by-step description of everything you did to determine their values. (Do not include the <u>*values*</u> of the responding variables here—you will present those in your Data & Observations section.)
- Any significant things you did as part of the experiment besides the ones mentioned above.
- Never say "Gather the materials." This is assumed.

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Data & Observations

This is a section in which you present all of your data. Be sure to record every quantity specified in your procedure, including quantities that are not changing (your control variables), quantities that are changing (your manipulated variables), and quantities you measured (your responding variables). ***Remember to include the units!***

For a high school lab write-up, it is usually sufficient to present one or more data tables that include your measurements for each trial and the quantities that you calculated from them. However, if you have other data or observations that you recorded during the lab, they must be listed in this section.

You must also include estimates of the *uncertainty* for *every quantity that you measured*. You will also need to state the calculated uncertainty for the final quantity that your experiment is intended to determine.

Although calculated values are actually part of your analysis, it can be more convenient (and easier for the reader) to include them in your data table, even though the calculations will be presented in the next section. However, you should check with the person for whom you are writing the report before doing this.

Analysis

The analysis section is where you interpret your data. Your analysis should mirror your Experimental Design section (possibly in the same order, but more likely in reverse), with the goal of guiding the reader from your data to the quantity that you ultimately want to calculate or determine.

Your analysis needs to include:

- A narrative description (one or more paragraphs) of the outcome of the experiment, which guides the reader from your data through your calculations to the quantity you set out to determine. For a high school lab report, it may be helpful to present this description in "Claim, Evidence, Reasoning" (CER) format:
  - **Claim**: the answer to your objective (which will also appear in your Conclusions section). If your objective was to determine the velocity of a squirrel, then your claim would be something like "The average velocity of the squirrel was found to be $4.2\,\frac{\text{m}}{\text{s}} \pm 0.5\,\frac{\text{m}}{\text{s}}$."
  - **Evidence**: your data and observations. E.g., "The tree was 25.4 m from where the squirrel started, and it took the squirrel 6.0 s to run to the tree."
  - **Reasoning**: a description of the relevant physics principles and a list of the equations that you used, in order. Your evidence and your reasoning combined should support your claim.

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- A full list of the equations that you used. (Do not include the algebra and results. The person reading the report will assume that you did the math correctly.)
- Any calculated values that did not appear in the data table in your Data & Observations section
- If you need to do a graphical analysis, include a linearized graph (either plotted by compute or meticulously plotted by hand) showing the data points that you took for your dependent *vs.* manipulated variables. Often, the quantity you are calculating will be the slope of this graph (or its reciprocal). The graph needs to show the region in which the slope is linear, because this is the range over which your experiment is valid. Note that ***any graphs you include in your write-up must be accurate and plotted to scale. If you plot them by hand, you need to use graph paper, plot the points at their <u>exact locations</u> on both axes, and use a ruler/straightedge wherever a straight line is needed***. (When an accurate graph is required, you will lose points if you submit a freehand sketch.)

  It is acceptable to use a linear regression program to determine the slope. If you do this, you need to say so and give the correlation coëfficient. However, you still need to show the graph.
- Quantitative error analysis. In general, most quantities in a high school physics class are calculated from equations that use multiplication and division. Therefore, you need to:
  - Determine the uncertainty of each of your measurements.
  - Calculate the relative error for each measurement.
  - Combine your relative errors to get the total relative error for your calculated value(s).
  - Multiply the total relative error by your calculated values to get the absolute uncertainty (±) for each one.
- Sources of uncertainty: this is a list of factors ***inherent in your procedure*** that limit how precise your answer can be. In general, you need a source of uncertainty for each measured quantity.

  Never include mistakes, especially mistakes you aren't sure whether or not you made! A statement like "We might have written down the wrong number." or "We might have done the calculations incorrectly." is really saying, "We might be stupid and you shouldn't believe anything else in this report." (Any "we might be stupid" statements will not count toward your required number of sources of uncertainty.)

  However, if a problem *actually occurred*, and if you *used that data point in your calculations anyway*, you need to explain what happened and why you were unable to fix the problem during the experiment, and you also need to calculate an estimate of the effects on your results.

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Conclusions

Your conclusions should be worded similarly to your objective, but this time including your final calculated result(s) and the calculated amount of uncertainty. You do not need to restate your sources of uncertainty in your conclusions unless you believe they were significant enough to create some doubt about your results.

Your conclusions should include 1–2 sentences describing ways the experiment could be improved. These should specifically address the sources of uncertainty that you listed in the analysis section above.

Summary

You can think of the sections of the report in pairs. For each pair, the first part describes the intent of the experiment, and the corresponding second part describes the result.

- **Objective**: describes the purpose of the experiment
  - **Experimental Design**: explains how the details of the experiment were determined
    - **Procedure**: describes in detail how the data were acquired
    - **Data & Observations**: lists the data acquired via the procedure
  - **Analysis**: describes in detail what was learned from the experiment, including calculations and uncertainty.
- **Conclusions**: addresses how well the objective was achieved

Use this space for summary and/or additional notes: