Template for a physics formal report using LaTeX

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We present brief guidelines and a LaTeXtemplate for writing a formal report. This template follows a format used in most reports and articles. This section, the abstract, is essential to all reports. Although it appears first, the abstract is written after the rest of the paper is done. The typical abstract length is < 100 words. It addresses the following: (1) What was done? Describe the study's purpose and motivation. (2) How was it done? Describe the experiment. (3) What was discovered? Provide quantitative and qualitative results. Describe the physical significance of your results.

1. INTRODUCTION

Technical reports and journal articles are a part of all engineering and scientific work. Reports communicate what you've discovered to the scientific and engineering community. Reports are not a typed up version of a lab notebook. They are much more concise in some areas, and more in depth in others. They focus on the results, analysis, and the physical implications of the experiment; these sections are often lengthier than the the lab notebook entry.

Your report should show evidence of your understanding of the experiment, follow the conventions used by the physics community to present scientific ideas and results, and use concise and correct English. You are expected to use LaTeX, a document preparation system used by scientists and engineers. LaTeXtypesets equations, and integrates figures, footnotes and references in the text.

This section, the introduction, describes the subject and scope of the study. Address the following questions: (1) *What are you studying?* Describe the topic and provide some background on the subject. (2) *Why is it interesting?* Provide some motivation, either using applications or research questions. (3) *What's the purpose of this study?* The topic is large, so be clear about what part of it you're researching. And (4) *What did you do and find?* For example, we report measurements of X to learn Y. We found Q and P.

The introduction for this paper is 1-3 paragraphs long.

2. THEORY

This section provides the theory related to the experiment. Since Electronics is a lab class, you're expected to emphasize the experimental nature of your study. Therefore, keep your theory brief, perhaps 1-3 paragraphs. At times, it may make sense to combine the introduction and theory sections into one long Introduction section.

The section addresses the following questions: (1) *How do we theoretically describe what you're studying?* Give a physical, conceptual description and a mathematical description. This can be really short: a sentence or two. You'll talk more about theory in the discussion section. (2) *What special case are you considering and what are the resulting equations?* Describe the special case, list the assumptions that go with it, and provide the resulting equation. Don't include full-on derivations.

You'll need equations in this section, and in following sections. Use numbered, single-line equations for important equations. This emphasizes their importance and makes it possible to refer back to them. Introduce the equation and define its variables in the surrounding text. For example, the magnitude of the electric field E of a from a straight line of charge is

$$E = \frac{\lambda \ell}{4\pi\epsilon_0 y\sqrt{y^2+(\ell/2)^2}} \tag{1}$$

where ℓ is the length of the line and λ is the line charge density. Keep in mind that Eqn. 1 is for a point y along the line's perpendicular bisector.

Related equations, like those in a derivation, should be grouped together. For example,

$$\left\{ abc123456abcdef\alpha\beta\gamma\delta1234556\alpha\beta\frac{1\sum_b^a}{A^2} \right\} \tag{2a}$$

$$\begin{aligned} \mathcal{M} &= ig_Z^2(4E_1E_2)^{1/2}(l_i^2)^{-1}(g_{\sigma_2}^e)^2\chi_{-\sigma_2}(p_2) \\ &\quad \times[\epsilon_i]_{\sigma_1}\chi_{\sigma_1}(p_1). \end{aligned} \tag{2b}$$

Less important, but necessary equations, are placed within the text. For example, the wavefunction is given by $\vec{\psi_1} = c_0|0\rangle + c_1|1\rangle$, where $|0\rangle$ and $|1\rangle$ are the ground and first excited states of the simple harmonic oscillator. Or the quantity $T = kq\int_a^R(r^2-b^2)^{-1/2}dr\int_{\pi/3}^{\pi}\sin^2\theta d\theta$ may be something to calculate.

3. EXPERIMENT

The experiment section describes the setup and procedures. In this course, there's always a circuit diagram and possibly a schematic of the measurement setup.

An example first sentence of an experimental section: The circuit for measuring the current-voltage (IV) characteristic of a passive element consists of a power supply, an ammeter and a voltmeter, as shown in Figure 1.

The reader needs to understand the essentials of how the experiment was run, but they're not going to repeat

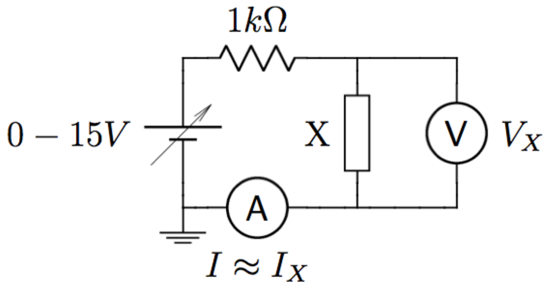

FIG. 1: In the caption, include a title, then describe the figure. Include specific issues or procedures in the caption. Don't repeat it in the text. For example: Circuit for measuring the IV curve of a passive element. The passive element is represented by X. Voltage and the current associated with X are measured with a voltmeter and ammeter. The 1kΩ resistor sets a maximum of 15mA for this circuit.

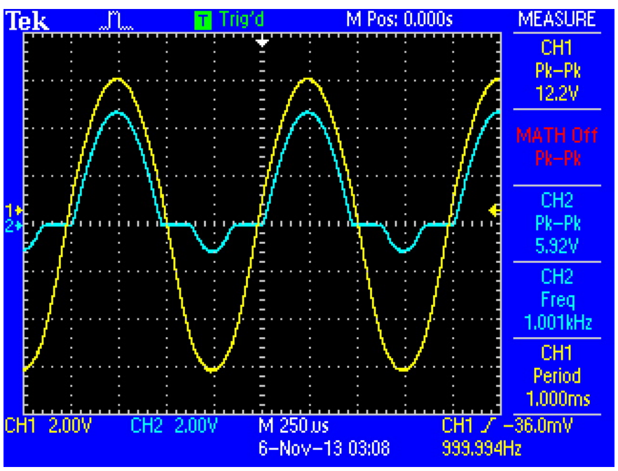

FIG. 2: Input and output for circuit 1 at a frequency of 1kHz. The input voltage is given by the yellow trace, and the output by the blue trace. Peak-to-peak values were

it. DO NOT give step-by-step instructions. Instead, describe what you measured and how you measured it in only a few sentences. Take another sentence or two to describe how you determined uncertainties for each measured value. For example: We measured the voltage across- and the current through- the element for several values of the supply voltage. Measurement uncertainties are based on the the DMM accuracies of 1.8% and 2% for voltage and current measurements, respectively.

4. RESULTS

Some papers, if possible, have one graphic showing some kind of raw data. For example, a scope trace showing input and output voltages. Figure 2 provides an example. DO NOT show all your raw data unless you have a very, very, very, very good reason.

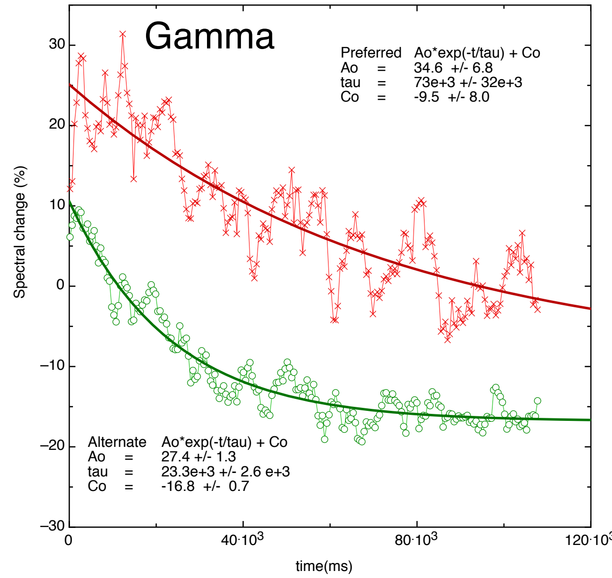

FIG. 3: Spectral change as a function of time, ERS(t), for the gamma band in the preferred and alternate conditions. The solid lines are fits to an exponential decay.

If you calculate a quantity from the raw data, describe it here. Include also a brief description of your error propagation. For example: From measurements of v_{in} and v_{out}, we calculated the amplitude of the gain $|G| = |v_{\text{out}}|/|v_{\text{in}}|$ and the phase shift, $\phi = \frac{t}{T}2\pi$. The uncertainties are $\frac{\Delta|G|}{|G|} = \frac{\Delta v_{\text{out}}}{v_{\text{out}}} + \frac{\Delta v_{\text{in}}}{v_{\text{in}}}$, and $\frac{\Delta\phi}{\phi} = \frac{\Delta t}{t}$.

Summarize these more useful calculated values in a table, an example of which is given in Table I, or a graph. We usually choose graphs over tables, since we're often more interested in behavior as opposed to specific values. Figure 3 provides an example. Describe what's going on. Point out dependences, maxima, minima, limiting behavior, or whatever features are worth emphasizing.

Include theoretically expected values, or a fit to theory, for comparison, if it's possible. If you're using a graph, include the theoretical curve or fit on the same graph as the data, as shown in Figure 3. If you're using a table, create a column for the expected values.

TABLE I: A example table with footnotes. Note that several entries share the same footnote. Inspect the LaTeX input for this table to see exactly how it is done.

	r_c (Å)	r_0 (Å)	κr_0		r_c (Å)	r_0 (Å)	κr_0
Cu	0.800	14.10	2.550	Sn[a]	0.680	1.870	3.700
Ag	0.990	15.90	2.710	Pb[a]	0.450	1.930	3.760
Tl	0.480	18.90	3.550				

[a] Here's the first, from Ref. [1].

5. DISCUSSION

5.1. What to write about

The discussion should be the longest section. This section addresses the following questions:

To what extent do your experimental results agree with theory? Usually, we're comparing experiment to theory, so where's where you get to fully answer this. Support your answer with specifics from your results. Your results may not completely agree with theory. If not, discuss possible reasons. For example, is it experimental design, equipment limitations, or perhaps the theory is incomplete or doesn't extend to that range? This is going to take more than 1 paragraph.

What do your results mean? Interpret your results physically. For example, do your results show that the quantity q is a constant, or does it have a dependence and, if so, what is that dependence? What does the peak in your graph mean? This is definitely going to take more than one paragraph.

Any implications or final thoughts? How does this experiment relate to, or have implications for, other experiments? For example, it might validate or be in conflict with a previously published results. Can you suggest further work to that answers questions that this study brings up, or perhaps to clear up and questions that weren't answered by this study? This might just be one paragraph.

At times, the discussion may have subsections. Here's a subsection on writing:

5.2. Guidelines for writing

The paper must be logical, with all facts presented in order. For example, everything you need to know in order to understand statement 15 was provided in statements 1-14. It also means that it's obvious how each part of your paper fits into (and is essential to) the overall picture. Logical order and clarity often results from following the expected structure of a paper: introduction, theory, experiment, results, discussion, and conclusion sections.

One of the ways to emphasize whether a fact or a point you'd like to make is important is the length of the text you devote to it. Write more for things that are important. Write less for less important matters.

Reports use paragraphs and sentences, not bulleted lists or phrases like in presentations or lab notebooks. Begin each paragraph with a topic sentence that expresses the main idea for the paragraph. Put less important material later in the paragraph.

You're encouraged to use "we" or "I". This makes it easier to write active sentences, which are preferred over passive sentences. Use the past tense for procedure and analysis, and the present for emphasis or conclusions. For example "Since we observed an interference pattern, we conclude that electrons are waves." Although we use "we" and "I", there's an expected level of formality to a paper.

Finally, references are required. Read over your paper. For each idea that isn't originally yours, provide a reference that the reader can look up if they want to know more about it. The appropriate way to incorporate an idea from a source is to put the original text aside and state the idea in your own words [2]. Then add the reference to the end of that sentence [3]. If you're using someone else's graphic, cite them [4].

This paper is expected to be about $4 \pm \frac{1}{2}$ formatted pages long, including figures and references.

6. CONCLUSIONS

This should be one paragraph. Report all your quantitative results with appropriate significant digits, units, and uncertainties, e.g. Q = (2.12 ± 0.06) disintegrations s^{-1}. Report your qualitative results. For example: "the theory for XYZ was found to model our data well for very low ($f \ll f_c$) and very high ($f \gg f_c$). Deviations from midrange frequencies suggest that..."

[1] Bevington and Robinson, Data Reduction and Error Analysis for the Physical Sciences - 3rd Edition, McGraw-Hill, [2003]

[2] Choose references conservatively. In general, books, textbooks, articles, equipment and lab manuals, have all been reviewed thoroughly by people who work in that field. In general, websites are a last resort for two reasons: (1) they change over time, (2) they rarely undergo review by people in the discipline. If you have no choice but to use a website, choose higher-education sites, government lab sites, or companies with well-established research divisions.

[3] Melissinos, A.C., Napolitano, J., Experiments in Modern Physics - 2nd Edition, Academic Press, [2003]

[4] Professor C. Ray, Personal Communication

Acknowledgments

MMR liberally used large sections of MIT's sample guide.