A Practical Guide to Writing in Physics Courses

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0 Introduction

Effective scientific writing is crucial for success in physics courses. This guide provides practical tips and clear instructions to help students master scientific writing for various needs, including formatting professional emails to professors, presenting well-structured solutions to homework and exams, and composing comprehensive laboratory reports.

Here is a short list of commonly used word processing software options with equation capabilities:

- LaTeX[1]
- Google Docs [Goo][2]: See [Goo] for equations.
- Microsoft Word[3]: See [Mic] for equations.

[1] `https://www.latex-project.org`
[2] `https://docs.google.com`
[3] `https://www.microsoft.com/en-us/microsoft-365/word`

1 E-Mail Writing

Professional communication via email is essential in academic settings. When contacting professors, TAs, or other academic staffs, keep the following in mind:

- Email Address: Use a professional email address, ideally your institutional or shcool-provided account.
- Subject Line: Write a clear and concise subject that includes the course identifier. This enables recipients understand the context.
- Body: Structure your email body for clarity and readability.
  - Opening: Begin with the recipient's name.
  - Line Breaks: Separate paragraphs to improve readability.
  - Introduction: Briefly introduce yourself, including full name and relevant course information.
  - Main Content: State your question or request. Focus on one primary topic per email to avoid confusion.
  - Closing: Add an appropriate sign-off with your name.
- Attachment: If you include attachments, mention them in the email body and briefly describe their contents.
- Proofread: Always proofread your email carefully before sending.

For further examples of best practices in professional email communication, see [Rob20]. An example of poor email etiquette is illustrated in Figure 1.

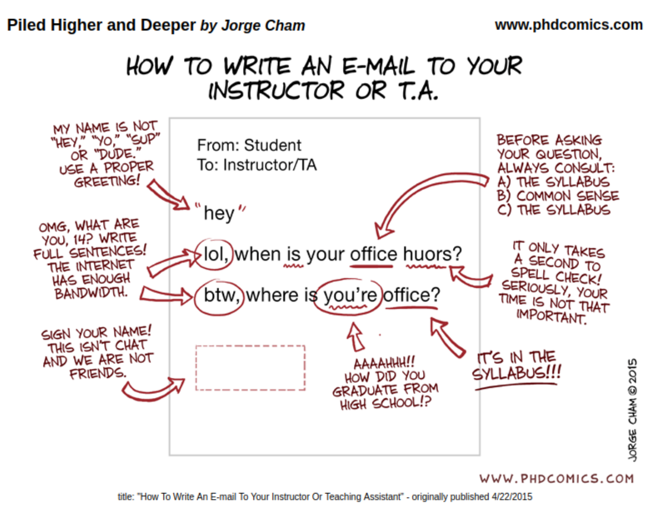

Figure 1: Example of an unacceptable email, adapted from [Cha15].

2 Solution Writing

A good solution guides readers through your reasoning without requiring much to fill in large gaps.

2.1 Solve, Substitute, and Round-off

When tackling problem-based exams, it is key to understand what the problemm is asking. Figure out a plan to solve it, and then carry out. Always check-it-twice your results – the signs, units, and the order of magnitudes. Highlighting final answers, using underline, **boldface**, $\boxed{\textit{boxed}}$, etc, is a great way to make them stand out.

Example 1. Let us look at a free-fall motion starting from rest. The position of the falling object at time t is given by $-\frac{|g|}{2}t^2$ and the velocity is $-|g|\,t$, where $|g| = 9.81\,\mathrm{m/sec}^2$ is the magnitude of downward gravitational acceleration. Find the falling object's velocity at height $h = -10.0\,\mathrm{m}$.

1. Identify knowns and relevant equations:

   The object's position at time t, relative to the initial point, is $-\frac{|g|}{2}t^2$. We know $|h| = 10.0\,\mathrm{m}$ and $|g| = 9.81\,\mathrm{m/sec}^2$.

2. Solve:

   Let T be the time when the object reaches $h = -10.0\,\mathrm{m}$:

   $$-\frac{|g|}{2}T^2 = -|h|\,. \tag{1}$$

   Solve for the time of fall T:

   $$T = \sqrt{\frac{2\,|h|}{|g|}}. \tag{2}$$

   The corresponding velocity is $-|g|\,T = -|g|\sqrt{\frac{2|h|}{|g|}} = -\sqrt{2\,|h|\,|g|}$.

3. Substitute and round-off.

   The speed at $h = -10.0\,\mathrm{m}$ is:

   $$\begin{aligned}\sqrt{2\,|h|\,|g|} &= \sqrt{2\times 10.0\,\mathrm{m}\times 9.81\,\mathrm{m/sec}^2}\\ &= \sqrt{2\times 10.0\times 9.81}\mathrm{m/sec}\\ &= 14.007\cdots\mathrm{m/sec}\\ &\approx 1.40\times 10^1\,\mathrm{m/sec}.\end{aligned} \tag{3}$$

   Therefore, the velocity at height $h = -10.0\,\mathrm{m}$ is $\boxed{-1.40\times 10^1\,\mathrm{m/sec}}$.

2.2 Mathematical Proofs

Understanding mathematical proofs can be tough. Writing can be even tougher. Some problems require students to demonstrate mathematical reasoning, often as a formal proof. Here is breakdown of how to approach proving a mathematical claim with proper logic and rigor:

- State the Claim: Describe what you want to show.

  > ... the initial statement is the best place to begin your thought process [Cen21]

- The Proof: Begin with "*Proof.*" and end with a *QED* symbol such as "■".

2.2.1 Elements of Mathematical Proofs

A mathematical proof must be self-contained and clearly present the logical argument. Here are key elements to include:

- Variables: Introduce your variables and declare symbols, and abbreviations used in the proof. Define what each represents.
- Quantifiers: State the type of each variable and whether it is universally quantified ($\forall$, "for all") or existentially quantified ($\exists$, "there exists").

According to [Cen21], many mathematical propositions are universally quantified implications of the form "for all [object of a certain type], if [hypothesis], then [conclusion]." Symbolically:

$$\forall x : H(x) \Rightarrow C(x), \tag{4}$$

where x is the universally quantified variable, $H(x)$ is the hypothesis, and $C(x)$ is conclusion. Proofs for this type of statement must begin with "Let x be ...."

Here are three common proof strategies:

1. Direct Proof – Often the preferred method whenever possible:

   Assume the hypothesis $H(x)$ is true and, using this assumption, definitions, and previously proven results, logically deduce the conclusion $C(x)$.

2. Proof by Contrapositive:

   Recall that $p \Rightarrow q$ – if p then q – is logically equivalent to $\neg q \Rightarrow \neg p$, see Table 1. Note that $\neg$ is the negation, also called logical not, $\vee$ is the logical or, and $\wedge$ is the logical and.

   Therefore, to prove $H(x) \Rightarrow C(x)$ for x, we can instead assume $\neg C(x)$ and prove $\neg H(x)$.

p	q	$p \Rightarrow q$
True	True	True
True	False	False
False	True	True
False	False	True

Table 1: The truth table for the implication $p \Rightarrow q$. Since both $p \Rightarrow q$ and $\neg p \vee q$ – not p or q – are false precisely when p is true and q is false, $p \Rightarrow q$ is logically equivalent to $\neg p \vee q$.

3. Proof by Contradiction:

   Assume the implication is false, i.e., $\neg(H(x) \Rightarrow C(x))$, which is equivalent to $H(x) \wedge \neg C(x)$. Use both assumptions $H(x)$ and $\neg C(x)$ to derive a contradiction.

   > ...in other words, you are indirectly proving that the original implication is true by showing that it cannot possibly be false.[Cen21]

Remark. *To disprove a universally quantified statement:*

$$\forall x : P(x), \tag{5}$$

where $P(x)$ is a proposition, find a counterexample – a specific x_0 for which $P(x_0)$ is false. The simpler the counterexamples are generally better.

Example 2. Prove that two complex numbers w and z are equal iff for every $\epsilon > 0$, it follows $|z - w| < \epsilon$.

Since this is an "if and only if" statement, we must prove both implications:

1. Direct Proof – "only if" part:

   Proof. If $z = w$, it follows $|z - w| = 0$. Therefore, for every $\epsilon > 0$, $|z - w| < \epsilon$ holds. ■

2. Proof by Contrapositive – "if" part:

   The "if" part in universally quantified implication form is:

$$\forall \epsilon > 0 : |z - w| < \epsilon \Rightarrow z = w. \tag{6}$$

   The contrapositive form is:

$$z \neq w \Rightarrow \exists \epsilon > 0 : |z - w| \geqq \epsilon. \tag{7}$$

   Proof. Assume $z \neq w$. Let $\epsilon := |z - w|$. Since $z \neq w$, $\epsilon > 0$. Thus, $|z - w| \geqq \epsilon$. ■

3. Proof by Contradiction – "if" part:

   Proof. Suppose $|z - w| < \epsilon$ for every $\epsilon > 0$, but $z \neq w$ for contradiction. Let $\epsilon_0 := |z - w|$. Since $z \neq w$, $\epsilon_0 > 0$. By definition $|z - w| = \epsilon_0$, but by hypothesis, $|z - w| < \epsilon_0$, which is absurd. ■

2.2.2 Grammatical Rules

Standard English grammar rule apply to mathematical writing. Here are some key points to keep in mind:

- A sentence must begin with a word, not with a mathematical notations. For example, instead "$I = [0, 1]$ is compact," write "The unit interval $I = [0, 1]$ is compact."
- A sentence must end with appropriate punctuation.
- Use quantifiers $\forall$ and $\exists$ carefully in formal writing. Words like "for all" and "there exists" are often better than symbols.
- Take advantage of mathematical notation. For example, instead "let n be a member of the set of natural numbers" write "let $n \in \mathbb{N}$."

Example 3. For any non-negative integer n, prove that $n^3 + 2n$ is divisible by 3.

Proof. We will prove this claim using mathematical induction:

- Base Case

  Let $n = 0$. Then $n^3 + 2n\big|_{n=0} = 0$.
- Induction Step

  Let $n \in \mathbb{N}$. Assume $n^3 + 2n$ is divisible by 3. This means there exists some $m \in \mathbb{N}$ such that
  $$n^3 + 2n = 3m. \tag{8}$$
  Consider $(n + 1)^3 + 2(n + 1)$:
  $$\begin{aligned}(n+1)^3 + 2(n+1) &= n^3 + 3n^2 + 3n + 1 + 2n + 2 \\ &= n^3 + 2n + 3(n^2 + n + 1) \\ &= 3m + 3(n^2 + n + 1).\end{aligned} \tag{9}$$
  Since both m and n are integers, $(n+1)^3+2(n+1) = 3\left(m + n^2 + n + 1\right)$ is divisible by 3.

By the principle of mathematical induction, $n^3 + 2n$ is divisible by 3 for all $n \in \mathbb{N}$. ■

3 Report Writing

Report writing is a key part in physics laboratory courses. There are many different types of reports and writing styles, but here we will focus on a specific, common format.

> . . . reports are heavily organized, commonly with tables of contents and copious headings and subheadings. This makes it easier for readers to scan reports for the information they're looking for. [Ell14]

Your report should include the following sections:

(A) A Title Page
   - Title of the report
   - Names
   - Date of lab performance

(B) Body
   - Learning Objectives
   - Theoretical Background
   - Procedure
   - Experimental Data and Graphical Analysis
   - Sample Calculations and Error Analysis

(C) Conclusion and Citations

The original "ABC" report format is adapted from [Kez10].

3.1 A Title Page

- Title:

  The title of a report can differ from the experiment title, but it should clearly carry the main focus of the lab activity.

- Names:

  Include your name and the names of your lab partners.

  > When you turn in a work bearing your name, the expectation is that you are submitting work that you have done on your own. That's part of what putting your name on an assignment means: that the work contained inside it is yours, unless expressly stated otherwise. [Bai17]

  See also §3.3.

3.2 Body

The body of your report should flow logically from general concepts to specific details.

- Learning Objectives:

  State the goals of the experiment and analysis.

- Theoretical Background:

  Discuss the relevant theoretical frameworks, methods, concepts, equations, and formulae. Your report must be self-contained, i.e., a reader should be able to understand the background theory without needing to consult other sources.

- Procedure:

  Provide a step-by-step description of the experimental procedure, similar to an instruction manual. Use visual aids such as photos and diagrams to enhance clarity. A well-written procedure section allows others to reproduce your experiment.

- Experimental Data and Graphical Analysis:

  Record and present all results in appropriate data structure. For each graphical analysis, include a clear heading, caption, title, axis labels, units, etc. Refer to [TT19] for rules and style conventions for axis labels in SI units.

- Sample Calculations and Error Analysis:

  Show how you used your numerical data to calculate the results. If you encounter relatively high error, this section is a good place to demonstrate your calculations detail, as it may help you identify any error in your analysis.

3.3 Conclusion and Citation

Provide a concise summary of your work, from the experiment to the analysis.

- Conclusion:

  This section should answer the learning objectives stated at the beginning of the report. All statements must be supported by objective and quantitative evidence.

- Citation

  As quoted in §3.1, all material in your report should be your own original work unless explicitly cited.

  > A "citation" is the way you tell your readers that certain material in your work came from another source. [Por17a]

For information on several standard citation styles, see [Por17b].

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