Writing about Physics

One of the best ways to clarify your thinking about the conceptual problems posed in your physics courses is to write about them. Writing forces you to think: to analyze ideas and arguments, to provide reasons and evidence for your own judgements and assertions, and to explain cogently to yourself and others some of what makes physics so intriguing to both specialist and layperson.

The way you use language affects the clarity of your thought and argument. Scientific writing requires its own types of logical organization, clear sentence structure, and precise word choices. The guide below includes tips on clear scientific style that are based on examples from research publications and from popularizing works. (It was created originally for PHY265F, an introduction to quantum physics.)

Checklist for Writers and Graders

The checklist has been drawn up to apply the general grading standards in the Faculty of Arts and Science (see the official grading statement in the online Calendar). You can expect your written assignments to receive grades in accordance with the following standards:

- An A paper shows all the qualities mentioned below. Its combination of fresh ideas, good reasoning and clear style keeps the reader's interest and attention throughout.
- A B paper shows most of the qualities mentioned below, and has at least some passages that command the reader's attention.
- A C paper shows some of the qualities mentioned below.
- A D paper (or below) lacks many of the qualities mentioned below.

Keep the following questions on hand for guidance in writing short assignments and longer research papers. (TAs will find them useful too as a guide for grading and commenting on student work.) The numbered sections of this guide set out further explanations and examples for each point mentioned—follow the links.

1. Have I fulfilled the assignment directions?
2. Do I have a clear point that knits together everything I say?
3. Have I created a structure that explains my ideas clearly and logically?
4. Have I supported my ideas with explanations and reasoning?
5. Have I integrated my sources with my own ideas?
6. Do my paragraphs lead the reader through my ideas step by step?
7. Does my style communicate readily to my intended readers? (CHECK: suitable word choice, logically structured sentences, freedom from distracting errors in grammar, spelling, and punctuation)
8. Have I proofread my work? Have I used standard format?
Advice and Explanation of Checklist

1. Know where you're aiming

When you're being marked on your writing, it's only wise to read your assignment sheet carefully. Assignments in your physics courses may surprise you. Notice what kind of reasoning they ask you to exercise (description, analysis, argument, speculation?), what reading and listening you're expected to do (from Newsweek or from Physical Review?), and what readers you're writing for (your fellow-students in or outside the class, non-specialists interested in science, experts who know more than you do about their specific area?). You can also ask your course TAs to check your interpretations. See this webfile on Understanding your Essay Topic for further advice.

2. Getting started: have a point and make it clear

Think of your writing as a way of asking and answering questions about your course topic -- or at least exploring them, since few questions in such fields as quantum physics or evolutionary biology have clear black-and-white answers. Start by considering what question underlies the given (or chosen) topic. Write it out to guide your own thinking. Change the wording if necessary to clarify your thinking. Then try out various ways of answering that question, doing as much reading, calculation, and thinking as you can for each type of piece.

Now write up an account of your thinking. Start by defining the question you've chosen to look at. Then indicate the best way you found to answer it. Both those things make up the point of your piece (not just the question, not just the answer). You will probably have a hypothesis (a tentative answer, needing to be tested and argued) rather than a thesis (a point to be proved). See this web file on when and how to use a thesis statement.

Use your title to capture the essence of your ideas. It can be interesting as well as precise, even for an academic piece. A title may be a phrase (e.g., "Deepening the Quantum Mysteries," "Three Proposed Quantum Erasers") or a full sentence—often a question. It may include an explanatory subtitle (e.g., "When Can Light Go Faster Than Light? The Single-Photon Tunneling Time and its Measurement via Quantum Interference").

3. Create a logical structure

Structure the piece to outline a clear path for the reader to follow in exploring the question with you—you don't have to tell us about all the wrong turns you took. Know what your objective is: do you simply want to communicate some claim, or are you trying to convince your reader of a particular position? Avoid simple formulas (e.g. the five-paragraph essay) that may not do justice to the intricacies of your explanation or argument; allow the logic of your objective to dictate structure.

You can use some creativity to find the best order for your ideas. Just make sure that your readers know where you're going and that they can follow you along. You may find a point-form
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Outline useful for planning. Creating one from an existing draft (listing one point per paragraph) is a good way to check whether your ideas flow logically from one another and form a coherent whole. Then you can look back at your prose and see whether each successive idea follows smoothly and directly from the preceding one. Check also that the introduction and conclusion match each other and what you said in the body of the piece. (See of this guide for suggestions on paragraph development.)

4. Explain your ideas

Some of your assignments may ask you to write for your fellow-students or for a popular readership; others may ask you to write for professors and experts in the field. Be sure you know where you're aiming. Don't write just to display your knowledge—work at sharing it. Consider these issues:

- What facts or evidence are essential to make my point? How can I work these into the explanations without weighing down the piece for my intended audience?
- How much does the reader know, and what should I explain? (e.g. terminology, mathematical formulas, historical references)
- Have I been balanced and fair? Have I acknowledged the strengths of opposing positions, and yet confidently and firmly presented my own?
- Am I satisfied with my presentation, and have I drawn confidently on my own insights? Has this writing exercise helped me to think clearly about the issues?

5. Read, listen, and write critically

To do justice to your complex subject, don't just borrow ideas from sources and stitch them together. Of course, like any scientist, you will build in what other people have thought. But show that you are doing your own thinking—seek out opportunities to comment on your sources. (Read about further strategies for critical reading and writing.)

- Read your sources with attention to context, looking for the author's intentions and type of argument. Make notes that reflect your analysis, not just the content of the piece.
- Tell your reader why you are convinced by an argument, and show why you may resist some aspects or implications.
- Compare any one reading to other ideas on the same topic, and show how they are related to each other as sources, extensions, or disagreements.

In the sciences, you should quote very seldom, but it's still worthwhile to mention names and give your reader the sense of being part of the conversation with leaders in the field. (See the U of T file on How Not to Plagiarize on ways to integrate your sources into your own prose.) In formal academic pieces such as research articles or reports, use a standard and consistent method for acknowledging your sources. (See another U of T webfile on Standard Documentation Formats for ways of handling that.) For less formal pieces, you may not need to be so precise about giving details like page numbers, though you'll still gain by name-dropping. Ask your
instructor or TA if you need to give formal references for the short assignments in this course.

6. Be focussed and coherent

Any written piece earns readers' respect and attention by maintaining focus on a central point, stating it clearly and then offering explanations and support. In science writing, there's a special satisfaction in being able to follow through a sequence of reasoning where all the ideas, sentences, and details fit together clearly.

To make that possible in your work for this course, divide even the short assignments into paragraphs that lead your readers through your ideas step by step. Use each to show where you are in exploring your question. It's advisable to start most paragraphs in the body of the paper with a topic sentence relating back to your overall point. These sentences serve as guideposts along the path. For more advice, see the web file Developing Coherent Paragraphs.

To create the kind of coherence and "flow" you need, follow these maxims:

- Stick to your message, topic, or idea consistently throughout the piece; don't waste space with irrelevancies
- Make every paragraph count: pace and sequence your information or argument to guide the reader right through to the end
- Develop smooth transitions within and between paragraphs
- Maintain a writing style and voice that is appropriate for your audience. (See the section, below, on Differences Between Formal and Informal Style.)

7. Be clear

Since the subject matter in science courses is often complex, make your style as simple as possible so as not to create further challenges for yourself and your reader. Here are some basic principles for clear scientific style.

a. Use the simplest words that will carry your meaning

Fight the tendency to impress your readers with your vocabulary. The subject is already impressive enough. Keep your words simple and ordinary for the sake of communication—and also to keep your own head clear. Of course you will use technical or mathematical terms as shortcuts when writing to people at the same or higher level of expertise. But if there's any chance your readers won't know such terms, offer a definition nearby. There are many ways to work definitions into sentences:

- The step height $W$ is called the work function of the metal and is typically a few electron-volts.
- The photoelectric effect (the ejection of electrons from a clean metal surface when light falls on it) provides strong evidence for the existence of photons.
- Probabilities are the odds that something is going to happen, or that it is not going
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to happen.

Remember that scientists (including the busy instructors and TAs who will be grading your pieces) have no patience for unnecessary words. Use analogies and colourful phrases to express your own interest in the subject, but don't rely on them to cover up weak reasoning. Clichés (overused metaphorical phrases) are especially annoying when you're asking the reader to work hard at a difficult subject. You will need some qualifiers such as "in this case" or "for the most part," but overuse makes you seem nervous. Avoid passive voice when possible too: it's often wordy and roundabout. The following pairs of examples (one from a scholarly abstract, the other from a magazine article) show the benefits of clear concise style. (For a review of ways to achieve conciseness, see the U of T webfile Wordiness: Ways to Avoid It).

- **NO** It is our desire at the present moment to construct an experimental process, with all the means at our disposal considering the complexity of the wild and wonderful world of atoms, that will demonstrate to the world at large (upon its conclusion in due time) some of the very fascinating ways that certain atoms manage to tunnel themselves through what might be considered a barrier.
- **YES** We are in the process of building an experiment to study the tunneling of laser-cooled Rubidium atoms through an optical barrier.

- **NO** A number of tests have been carried out by the various people collaborating in this project, all of which have dealt with some of the more puzzling, arcane, and paradoxical predictions made by quantum theory. Among the more dramatic ones is the one that is called, in a rather amusing phrase, the "quantum eraser."
- **YES** The team has carried out several tests of the stranger predictions of quantum theory. The most dramatic is what they call the "quantum eraser."

b. **Use short complete sentences**

Keep your focus on one idea at a time, and make sure each point is complete and clear. Then you can choose to link your ideas logically, not by accident. You and your readers will be grateful to read more short sentences than long ones: that goes for both your popular writing and your more formal pieces. Note how often your readings use short emphatic sentences, even for complex and open-ended ideas.

- **Quantum Physics is the most successful theory for answering these questions. It has no competition.**
- **In other words, electrical charge is "quantized." It comes in chunks. In the case of electrical charge, all of the chunks are of the same size. Why this is so is one of THE unanswered questions in physics.**

c. **Match subject and verb**

The core of your sentence consists of a definite subject and a distinct verb. One thing to watch for in proofreading your work is that the subjects and verbs match (both singular or both plural). Keeping them close together helps.
The time they spent during the past ten years of experiments with lasers were wasted.

Ten years of experimentation with lasers were wasted.

NOTE: Data is officially a plural noun (the singular is datum, but nobody ever uses it). You'll keep out of trouble with the grammar police if you say "the data are," not "the data is." By the way, the plural of quantum is quanta.

NOTE: If English isn't your first language, you may find that you have trouble putting the final s in the right places. Check through your work for that detail so your reader doesn't have to keep filling it in. In short pieces, you may be able to go rapidly through each sentence looking at the subject-verb match. For longer pieces, check at least the first and final paragraphs. Try reading your piece out loud: if you hear yourself saying a final s, check that it's written down.

In real systems the potential energy is always a measure of the interaction between particles.

Quantum mechanics does not predict specific events, it does predict probabilities.

With this algorithm we need only five steps to obtain the desired result, with the other one, we need at least twenty.

Quantum mechanics, for all its ability to get into the world of the atom and beyond the overly-rigid rules of classical physics, which are no longer adequate for the wonderful world of today.

Here are some ways to structure your sentences to show different logical relationships and emphasis. Note how the specific punctuation confirms the intended logic:

iv. Separate sentences with a period (to sound decisive), adash (energetic), or a semicolon (balanced, formal).
   - Quantum mechanics does not predict specific events. It does predict probabilities.
Quantum mechanics does not predict specific events -- it does predict probabilities.
Quantum mechanics does not predict specific events; it does predict probabilities.

v. Join sentences with the simple conjunctions and, but, and or to show strong basic relationships, usually with a comma between (or occasionally a period for a dramatic effect).

The Great Machine runs blindly on, and all things in it are mere cogs.
Choose the method with five steps, or be ready to spend three more hours doing the problem.
We need to provide a mathematical proof in each instance. But what is a proof?

Absolute time, wrote Newton, "flows equally . . . ," but he was wrong.
Quantum mechanics does not predict specific events, but it does predict probabilities.

vi. You can occasionally insert one of the weaker linking words (such as however, thus, therefore, on the other hand, and accordingly) for a subtle effect of contrast or qualification. These cannot join sentences by themselves. A period, dash, or semicolon is still needed. Note the different positions available for the linking word.

Quantum mechanics does not predict specific events. However, it does predict probabilities.
Quantum mechanics does not predict specific events; however, it does predict probabilities.
Quantum mechanics does not predict specific events. It does, however, predict probabilities.

vii. Join sentences with a subordinating conjunction (such as when, where, because, if, and whether) to signal a specific logical relationship. Usually the conjunction comes at the start of the first sentence.

Because the second algorithm requires twenty steps, we chose to use the other one.

If we picture a moving particle, it is very difficult to imagine not being able to measure both its position and momentum.

Since we cannot determine both the position and momentum of subatomic particles, we cannot predict much about them.

Although quantum mechanics does not predict specific events, it does predict probabilities.

8. Check your work for mechanical flaws

Readers who come looking for interesting ideas have little tolerance for distracting detail errors that you could have fixed with a bit more care. Develop a system for checking through your work for correctness and consistency.

- Print it out at least once so you see it on paper.
• Don't trust your grammar-checker, except for amusement. The only thing it might help you with is recognizing passive voice: it gets that one right about two-thirds of the time, but it still can't tell you how to mend the problem.

• Do use your spell-checker, though, as the final step before printing. But you have to be the one to decide whether to accept its suggestions. Don't let your key words get changed just because the spell checker hasn't taken Quantum Physics.

• Flaws in punctuation may be a little more forgivable, but not when they interfere with the reader's understanding or spoil the emphasis you've carefully built up with sentence structure. Seek out advice on punctuation from a handbook or website, and use it to become familiar with the standard patterns.

Here are some pitfalls to avoid in any writing, especially when you're trying to play the role of guide or expert:

• confusion of it's (contraction for it is) and its (belonging to it), they're (contraction for they are) and their (belonging to them), you're (contraction for you are) and your (belonging to you)

• use of you to mean "people in general" ("You shouldn't trust classical physics.")

• random use of semicolons (see above on their structural function)

• overuse of exclamation marks, font style, bold, italics, capitals, etc. in an attempt to achieve emphasis

Stay out of trouble too by following the standard format for any manuscript:

• 12-point font, 1-inch margins, double spacing

• numbered pages after the first

• either indentation of the first line of paragraphs or extra spacing between paragraphs.

A Note on the Differences between Formal and Informal Style

You'll use both types of style in this course for different assignments, and you'll certainly use both types of writing in the future. Here's a review of specific differences. Use it to keep your style consistent in any one piece, and to make even your academic writing as interesting as possible without losing too much dignity.

ACADEMIC: Spell out words, use technical terms as needed, offering at least a running definition when you introduce them

POPULAR: Use contractions like "don't," keep technical terms to a minimum and make a production of explaining them on first use

ACADEMIC: Avoid using "I," but use "we" in explaining technical matters; rarely mention any specific people by name except famous experts

POPULAR use any pronoun except "you" to indicate "people in general"; refer to many specific people by name, including current scientists working on your topic
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ACADEMIC: Emphasize abstractions such as theories, concepts, and mathematical formulations; label any diagrams or charts
POPULAR: Give plenty of examples; use simplified diagrams

ACADEMIC: Use passive voice ("it has been demonstrated") when you need to indicate that any scientist could achieve the same experimental results and any thinker could follow the same reasoning pattern; but also use active voice frequently to make your account more dynamic and personal ("Steinberg used optical barriers to show that...")
POPULAR: Avoid passive voice and focus on people and what they did; use narrative form to explain scientific experimentation

ACADEMIC: State your points succinctly and confidently; make clear assertions and argue them cogently, offering firm support and rebutting opposing points
POPULAR: Acknowledge the difficulty of the subject, show empathy with the reader's likely confusion; give plenty of explanations and examples; note controversies and suggest that they're exciting

For Further Reference

All these books and websites are readable as well as informative. The books are all available in the U of T Bookstore. Find resources you like; then use them regularly.

W. Strunk, Jr. and E.B. White. *The Elements of Style*. A classic, highly recommended by many professors. Though not about scientific writing, it emphasizes clarity and explains its ideas clearly and amusingly. You can get Strunk's original 1918 course text online

M. Northey and M. Procter. *Writer's Choice: A Portable Guide for Canadian Writers*. An inexpensive book focussed on efficient production and editing of student writing. Much of the advice on style is also available free online through the Writing at U of T website—start with this list.


Maeve O'Connor. *Writing Successfully in Science*. An excellent handbook if you're going to be writing in your future studies or career (and you are). Use it now to get a sense of the different forms used and to check for conventions of capitalization and notation.

NASA on punctuation: bookmark this chapter of their big style manual for scientific writing

Hit Parade of Errors in Style, Grammar, and Punctuation: fast and amusing review of likely language errors and ways to mend them.

HyperGrammar at the University of Ottawa: a much more thorough review of grammar, if you ever want to give yourself an upgrading course.
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http://www.writing.utoronto.ca/advice/specific-types-of-writing/physics