Instructor's guide This is the policy for Contemporary Challenges, but could also be used in other classes

1 Basic format

- Blank white paper (8.5" x 11") is the best paper for scanning into Gradescope. It is also OK to use ruled paper. **Do not** use grid paper because scanned images of grid paper are hard to read in Gradescope.
- Write with dark colors that are easy to scan/digitize. **Do not** use red ink. **Do not** use faint-grey pencil.
- Leave space between the lines of math to make your answers easy to read.
- Leave enough empty space on the page for the grader's comments.
- Leave space between problems; No more than two problems per page.
- Very big and very small numbers must be expressed in scientific notation (for example, 1.2×10^6). You will lose points if you use decimal notation to express numbers that are greater than 10^6 or less than 10^{-3}. **Do not** use E-notation (for example, **do not** write 1.2E6).
- Circle your final answer.
- If you are typing your answers in LaTeX or other editing software, read the 9 Rules of Typography in Physics.
- When uploading your answer to Gradescope, follow the instructions to create pointers that link specific question numbers to specific pages of your scan.

2 Mathematical communication

Part of your grade for all homework and exams will be based on the quality of your mathematical communication. Effective mathematical communication enables others to read and evaluate (and learn from) your work. Effective communication aids your own thinking, and supports your collaborations with other scientists.

Mathematical communication aids thinking by facilitating external cognition. Our brains are powerful but have limitations. To solve challenging physics problems we need to offload our ideas and store them for later use. Learning to organize your reasoning clearly on paper will enable you to more easily and accurately solve more challenging problems. You can read and evaluate your own work, and streamline the process of finding errors that you may have made.

Diagrams Diagrams are a powerful tool for visualizing a physical system and connecting its details to your mathematical analysis. A well-drawn diagram can clarify relationships, streamline problem-solving, and often replace lengthy explanations. Make it a habit to sketch diagrams; they can save you a thousand words!

Defining algebraic variables Any variables you use must be defined. This can happen early in the problem, or in a figure, or right after an equation with a phrase like "where m is the mass of the particle".

Declaring numerical quantities Option 1: You could say "Assume that the specific energy density of gasoline is 40 MJ/kg".

Option 2: You could declare your assumptions in within an equality. In the example below, I've written enough to communicate my assumptions about the battery size, and the type of charger:

$$\text{time to charge the battery} = \frac{\text{storage capacity of battery}}{\text{charging rate}} = \frac{5 \times 10^7 \text{ J}}{5 \times 10^3 \text{ J/s}} = 10^4 \text{ s} \tag{1}$$

Units When a physicist writes down the numerical value of a quantity, they write the units next to the number (unless it's a dimensionless quantity). See the examples above.

Significant figures Use an appropriate number of significant figures. If you give an answer 6.70931309283 kg, you are probably claiming a level of precision that is impossible/unrealistic. If the problem is a zeroth-order estimate, use 1 or 2 sig. fig. to convey a precision of 10 to 20%. If you have a more refined answer, use 2 or 3 sig. fig. to indicate the appropriate level of precision.

Starting equation A starting equation is an equation that is not deduced from equations you already have written in your answer. You may have several starting equations in a given problem. Often, starting equations will be physical laws. In some cases your starting equations may simply be conversions. When the source of a starting equation is not obvious, you must describe where it came from (or why it is true) in words. For example, "From the Stefan-Boltzmann law...".

If you find yourself writing a lot more words than math, please check in with the instructor.

Following equation A following equation is an equation that can be mathematically shown to be true based on equations already present. In many cases, following equations do not require words to explain them. However, if it is not obvious what you did, then some concise words of explanation are important (like a comment in a computer code). For example, "Change the integration variable to $u \equiv 1/r$" or "Assume that all heat entering the water came from the rock".

For algebraic manipulations, it is sufficient to simple write the lines of algebra. It is unnecessary (and a nuisance) to write words such as "We now divide both sides of the equation by the m."

If you find yourself writing a lot more words than math, please check in with the instructor.

Equation sequences The equation sequence is a common idiom in mathematical communication. One side of the equation does not change:

$$\vec{F} = m\vec{a} \tag{2}$$
$$= m\frac{d^2\vec{r}}{dt^2} \tag{3}$$
$$= -mx_0\omega^2 \sin \omega t \tag{4}$$

In this idiom, we do not rewrite the left-hand side of the equation, but it is taken to be identical. Each expression on the right-hand side in this example is equal to the force.

Equate the leftside to the rightside Variables and numerical quantities must always be part of either a sentence or a mathematical eqution. For example, **do not write:**

$$\frac{5 \times 10^3 \text{ J}}{5 \times 10^7 \text{ J/s}} \text{(no!)} \tag{5}$$

In the example above, there is no equals sign (it is not an equation). It is not a statement that conveys meaning. It is analogous to a sentence with no verb.

Always check that the leftside and rightside of an equation have the same dimensions. For example, if the leftside has dimensions of length, the rightside must also have dimensions of length.

3 Writing a model answer for your term project

When you create your model answer for the term project, it should look like the answers to example exercises that you find in the PH315 textbooks (the *Sustainable Energy* textbook, and the *Six Ideas* textbooks). These model answers give the reader detailed explanations and guidence. Additionally, they often include sensemaking even if the question didn't explicitly ask for sensemaking.

Remind the reader of your goal At the start, write a sentence (or two) reminding the reader of the goal. For example, "We want to find how much heat is leaking out of a typical house." Use pictures/diagrams to help define the system and define what will be calculated.

Describe your assumptions When you construct a mathematical model of the physical system, you will likely need to make some assumptions. Clearly describe these assumptions and provide justification for each assumption, explaining why it is reasonable in the given context.

Layout the calculation The calculation is the heart of your answer. Show all quantities you used, and the mathematical steps you took to get to the final answer. Insert sentences/comments to explain significant steps in the calculation. These sentences/comments should be concise and useful. If you find yourself writing a lot more words than math, please check in with the instructor.

Sensemaking At the end of your answer, you might include a comment such as *"An energy leak of 1000 J/s would correspond to 24 kWh per day. This is consistent with my expectation that heating is a large fraction of the the typical energy consumption of a household, and I know that an average household uses 40 kWh/day)"*.

The type of sensemaking will differ depending on the question. A differnt example of a sensemaking comment is: *"This solution approaches the classical limit [fill in the details] when the number of photons is large"*.