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Physics 211, *Physics for Scientists and Engineers*

The Workshop Physics Activity Guide[1]

The authors of *Workshop Physics* have designed this course so that you can *discover* the laws and theories of nature on your own. Educational researchers have demonstrated that students engaged in hands-on-learning are far more likely to form accurate conceptual models and to retain these concepts longer than students who attend conventional lecture formats. Hands-on-learning is active, not passive. You don't watch the instructor do demonstrations. You do the demonstrations. You take the measurements. You do the experiments.

Workshop Physics uses a form of discovery learning called *guided*-discovery learning. You have a workbook, your activity guide, which leads you through exercises and experiments. Usually, after introducing a topic, it will propose an experiment, and prompt you to predict the outcome. It will ask you to justify your predictions. Then it will walk you through the experiment, and ask you to compare the outcome with your predictions. The authors have explicitly chosen experiments that overturn common misconceptions. This confrontation can be very effective—unexpected outcomes can be indelible learning experiences. We know this works when we hear, *"Why did that happen?"* However, students have to realize that there is no substitution for their active participation in the process. The students who really learn the material are the ones that take this process seriously, rather than seeing it as an ordeal they have to get through. The more you engage the material, the more you learn.

When scientists study the world through observations and experiments, they always keep a journal or notebook containing everything they do–their current understandings, predictions, observations, drawings, measurements, data, calculations, analysis, reflections, etc. Part of learning and doing science is keeping this notebook. We do not ask you to produce a formal notebook. Instead, you will practice doing a notebook when you fill out your Activity Guide. Almost all of the activities in the Activity Guide ask you to do the following things, which would normally be included in a scientist's notebook:

- Make predictions based on your current understandings.
- Make observations and measurements.
- Do calculations with your data or model your data.
- Organize your measurements and results in a table and graph.
- Discuss your observations and data and use them to come to some conclusion.
- Reflect upon your conclusions. How does your conclusion compare to your predictions and previous understanding?

Sometimes the activity guide will ask what appears to be a silly question. Something like this, "*Is the wall vertical*? *How do you know?*" In the beginning, this frustrates students to no end. Bear with us. We want you to begin to examine, even question, the underpinnings of many things that you take to be self-evident. Here is why. Many of the beliefs, concepts, and ideas, which we take to be obvious, are without justification. It gets worse. Many of the things we take to be self-evident are demonstrably false.

So how do we know when our ideas are wrong? We have to test them. We have to get into the habit of analyzing our thoughts. We have to slow ourselves down and take care not to leap to a conclusion. We have to test our reasoning and conclusions for validity and consistency. A Question like, *"How do you know when something is vertical."* Bedeviling as it is, is designed to give us practice with this type of self-dialog. If we ask students to define the word *vertical*, the common answer is "*Perpendicular to the ground*." All one has to do is stand on a hill to realize that that definition will not do at all. (So how should we define vertical? We'll let you think about it.) We call this process of examining and logically evaluating the reasons for an assertion *critical thinking.* It is one of the hallmarks of the scientific process. Some students feel harassed, even patronized, by questions like the one above: *"Why should I work so hard to define something that every one already knows!"* Our response is that most of you need to practice this type of thinking. It does not come naturally.

Learning to be precise and concise with language is another necessary skill, and it goes hand-in-hand with clear thinking. When you fill in entries in your activity guide, it forces you to think about the ideas you are trying to explain. Usually when you struggle to explain something in writing, it is a clue that there is something missing in your conceptual understanding. Don't fight this, use it as a tool to help you clarify your thoughts. Many scientists dialog with themselves in their writing in their lab book. A question we get often when students are making entries in their activity guides is *what can I safely assume*? The short answer is *do not make any statement that you cannot justify*. Do not obsess over this. You can get into an infinite regression defining words that you have used to define other words. There are reasonable stopping points. You will discover this as you practice. Be patient. You are not

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[1] Adopted from "*Filling out your Activity Guide*", by Dr. Chris Cline of Westminster College.

going to learn this skill over night. Ultimately, though, we want all of you to ask, and answer, these kinds of questions in all your studies.

Sometimes the questions in the Activity Guide appear to be redundant. However, it may be asking a similar question about a different idea. What is true in one situation might not be true in another. Acceleration may be a constant, but velocity is not. Sometimes the question *is* redundant. It will ask the same question in different ways. It is checking you here. Do you really understand the concept? It is probing your understanding from different directions. It is giving you practice testing your mental images. And, it is modeling the type of questions we want you to begin to ask yourself.

The following outline is a guide to help you properly include the above items when you fill out your Activity Guide.

1) Predictions

a) When asked for a prediction, again, it is our way to get you to probe, reflect, and critically analyze what you think you know. The correctness of your response is not the issue. We are not going to grade you down for an incorrect prediction. We will examine your responses for quality, consistency, and the depth of your analysis. Different students learn things in different ways. Therefore, it is essential that you investigate your *own* ideas and understanding about a phenomenon not the ideas of your partners. Although it is encouraged to discuss things with your partners, it is crucial that you answer the questions on your own.

b) State all your predictions clearly, using complete sentences and proper grammar.

c) Support your predictions using one or more of the following:
   i) Previous observations (usually in the previous activity, and sometimes in a previous unit).
   ii) Data or equations.
   iii) Some sort of logical reasoning, usually based on past experiences.

d) Re-read your prediction to make sure it says what you want and that there are no conflicting statements.

2) Observations and measurements

a) Give a *complete* description of your observations. Your goal is to make sure someone with your same physics background can understand what it is that you saw.

b) Make your description clear, unambiguous, and detailed. For example, the statement *"The cart moved"* is not nearly as informative as *"The cart moved from rest to the right, increasing its speed at a constant rate when the force was applied to the right."*

c) Use complete sentences and proper grammar.

d) If it helps in describing your observations, make some sort of sketch or drawing. However, a drawing only can supplement, not replace, your written description.

e) When making a measurement (for example, the mass of a cart), if possible make at least 3 measurements and report the average as the measured value and the SDM as the uncertainty.

f) Make sure your measurements have:
   i) The proper units.
   ii) An uncertainty.
   iii) The correct number of significant figures.

3) Calculations and derivations

a) All your calculations (and equation derivations) should progress in an organized manner, and not be scattered all over the page. If you make a mistake, just put a line through it, and go on. Keep in mind that this is practice for entries in a scientific lab book, or journal. Your peers should be able to follow what you did. Your calculations should start with the equation in symbol form, with any manipulations also being done in symbol form. Plug in numbers only at the end. Be sure to include units and use proper significant figures.

4) Data organization

a) Your data should be organized in a table, with proper headings and units in each column. Sometimes the Activity Guide provides the table outline for you, sometimes it doesn't. If there is no table outline, you must make your own.

b) Numbers should have the correct number of significant figures.

c) Report all your numbers with an uncertainty. (The uncertainty will determine how many significant figures to report.)

d) Quite often, a graph is an additional way to organize your data, particularly if you want to see if the data follows some sort of trend (i.e., linear, parabolic, or whatever). Whether the Activity Guide provides a graph outline for you, or you have to make your own graph, be sure that it includes:

i) A descriptive title.
ii) The proper scale on each axis.
iii) The proper labels, with units, one each axis.
iv) A legend, particularly if there is more than one data set on the graph.
v) Usually the only time a line or curve should go through your data is if it is the result of a model or a curve fit. Do not just *connect dots*.

5) Discussion and reflection

a) State your discussions and conclusions clearly using complete sentences and proper grammar.
b) When you are asked, "How well does your model fit the data?" Never say, "My model fit the experimental data well." The problem is that words like well, or good, only have meaning if you know the standard that you are using. How good is good? There will be some uncertainty associated with each of your data points. So, always answer questions like this quantitatively. A better answer would be, *"The uncertainty in each data point is +/- 5%. My model fit within the allowed uncertainty."*
c) The activity guide sometimes asks for justifications sometimes it doesn't. *You need to justify* ***all*** *your explanations and conclusions with your observations, data, graphs, and analysis.*
d) Always compare your conclusion with your initial prediction.
e) Re-read your conclusion to make sure it says what you want and that there are no conflicting statements.
f) Keep in mind that we are looking for evidence that you have a clear understanding of what you are observing and analyzing.

6) Additional remarks

a) *Have Fun*—We hope your experience in this course will be stimulating. Take the time to have some fun and try not to get overly stressed if you run into problems while working on your activities. Part of the process of science is learning to deal with the problems you run into. Try to be resourceful and develop creative solutions to any problems that arise. We will try to support you when you do. Science is very much an artistic endeavor and scientists often derive tremendous satisfaction in becoming deeply involved in projects.
b) *Ask Questions*—In this course, the format is such that you are actively engaged in discussions and activities with your fellow students. You will find times when everyone seems to be confused and yet it seems perfectly clear to you. Of course, there will be times when you are the one feeling frustrated and everyone else seems to have "gotten it." It is important to be able to explain things to others as well as to be able to understand another student's explanation. This interactive process is intellectually beneficial to both parties and you should engage in discussions whenever appropriate.
c) *Be a good partner*—This program is group based. That means that every one must share the load. Don't expect your partners to do your work for you. Take turns using the computer. Be empathetic. Lend a hand when your partner is having difficulties understanding some concept. Never harasses a group mate because they don't understand something.
d) *Use Your Head*—this course is designed on the assumption that you will make an honest effort to answer the questions in your Activity Guide. You will learn little if you just "whip through" the questions without having given them much thought. On the other hand, try not get too bogged down on any one question. If you are really having problems with something, it is possible you are interpreting the question differently than anticipated. Ask your instructor!
e) *Talk to the Instructor*—If you are having serious problems, come and talk to the instructor. Do not wait until you are so lost and frustrated that nothing can be done to help.