AP Physics C Summer Assignment

July 2020

Let us begin with a brief meditation on this poem, by Salvatore Quasimodo:

Everyone stands alone at the heart of this earth
Stunned by a ray of sunlight
And suddenly it is evening.

No matter how young we are, we cannot know how many years we may have on our journey. We should take advantage of the time we have before evening comes.

"Alone" and "stunned" are powerful and emotional words. They may remind us of times when we found ourselves at a place in life that was difficult, confusing, stressful, or lonely. Our school years can sometimes have painful moments where we feel particularly challenged and isolated.

But it seems to me we that don't have to stand alone, whether it be at the heart of the earth or elsewhere. We can walk, as well as stand. We can walk with others, and we can walk with a spirit of optimism. As another poet suggests, "Let us go singing as far as we go."

We have the opportunity this year to think deeply and well about physics, an essential part of the cultural heritage of humanity. Through the study of physics, we can not only <u>look</u> at the world around us but <u>see</u> it in a new way. Not everyone is so fortunate to have such an opportunity in their lives; let's not waste our chance this year to study and spend time working and learning together in fellowship.

We should recognize that some of the main concepts in the course are as profound as they are counter intuitive. Let us resolve to have patience with ourselves and encourage others as we go. Evening may indeed come, but before that we can build a little campfire for ourselves.

<u>A. Administrative</u>

Please enroll in our Google Classroom page. The code for that page is: mbmry6r

After schools closed in March, I started an online bulletin board to facilitate communication between students, located at www.montyfizz.com. Please go to that page and make an account using the "Register" link. For your user name, please use firstname.lastname (Example: Craig.Buszka).

You won't be able to see anything on Montyfizz until I approve your account.

What follows are some activities that can help you to take advantage of our time together, beginning on our first day. In addition to the resources listed below, I may prepare something for you to read ahead of our first lab, which I hope to attack on our first day of class.

B. On-Ramp to AP Physics C: Mechanics

Since we'll have students with a range of backgrounds enrolled in AP Physics C next term, I thought it would be a good idea to assign some work that could serve as a useful review for some folks and could help others come up to speed on the mechanics that we'll be working with during the first few weeks of the course.

There is a self-paced online course available to us called, "On-Ramp to AP Physics C: Mechanics." This course is intended to help students come up to speed, if you will, 'before their school year begins. The course description reads:

"This short course is intended for the high-school students who have taken an introductory-level physics course, acquired some background in Mechanics and intend to take a more advanced course – for instance, AP Physics C. The course helps the students refresh and strengthen their fluency with the mathematical tools and the fundamental topics in Mechanics: Kinematics, Newton's Laws and Laws of Conservation. The last unit of the course contains a comprehensive Final Exam. The students who completed this mini-course will be well-prepared to tackle more advanced course material in the fall."

You can register for the course here: https://www.edx.org/course/on-ramp-to-ap-physics-c-mechanics-2

There are various readings and problems to solve for the four units of the course. The developer said that he anticipates students will need 1-2 hours a week during the summer to complete the course. If you have a question that you can't resolve, feel free to reach out to friends or shoot me an e-mail.

On-Ramp to AP Physics C does not use calculus; this part of the assignment is just about the physics. If you'd like a textbook to refer to, see this link to a free download for an algebra-based college textbook: https://openstax.org/details/books/college-physics

Notes:

- The course has a "Progress" page which you can use to show you completed the course. Please upload an image of this page to the Summer Assignment in on Google Classroom.
- You can take the course at no cost to you. You do not need to upgrade to a "Verified Certificate," although they will try to tempt you to pay $25 to do so.
- Although I didn't find any errors on questions I tried, I encountered quite several issues with a physics course I took on the same platform two years ago. Examples of issues would be questions with typographical errors, or questions where the correct answer choice was marked wrong. This is only the second summer for the On-Ramp course, so they can expect to have some issues, I think.
- The developer recommends using either Firefox or Chrome.

C. The Essence of Calculus

The "C" in AP Physics C refers to the *calculus*, a set of mathematical methods that allow us to describe systems undergoing changes. Some of us will have had a year of calculus already, and others will be taking calculus for the first time in the fall. I'd like to help students in the latter category come into the AP Physics with enough background so that we can do some useful analysis following our lab on Day 1.

I've spoken to a number of peeps who have recommended a YouTube channel called 3Blue1Brown, particularly a series of twelve videos on "The Essence of Calculus," which you can find here:

https://www.youtube.com/watch?v=WUvTyaaNkzM&list=PLZHQObOWTQDMsr9K-rj53DwVRMYO3t5Yr

While these videos aren't developed for the specific purpose of helping you out in AP Physics C, they do discuss some concepts and tools that we will find quite useful in the course. The channel says it is "about animating math, in all senses of the word animate," and I think they deliver. The discussion really emphasizes the graphical representations of functions—consistent with one sense of the word "animate"—and, I think, illuminates conceptual ideas that can clarify the subject and energize the mind. I wish I had had a resource like this when I was a student, which was a long time ago, even before there were memes. The ideas here may inspire you to do some additional studying on a topic of interest, which I would encourage.

Each video is between 15-20 minutes in length. If I were you, I'd watch these videos one at a time, perhaps on successive days, and spend a few minutes writing down some key ideas after each video. Doing something active with something you learn can help concepts stick in your mind in a way that passively receiving information does not. If you keep your notes in a place where you can find them again, you may find it profitable to return to them later, when you can make connections between the ideas shared in the video and particular applications we encounter in physics.

D. Thinking About Teaching and Learning

At the end of this document is a section from *Teaching Introductory Physics*, a book by Arnold Arons. Arons was an influential figure among those educators who have sought to reform the ways science has been traditionally taught in the United States. The section I'm including here is from a chapter on critical thinking. It's written in a very dense way and may bear reading and re-reading at different times.

You may ask: What am I up to with this very dense, very serious reading? Some of the students in AP Physics C next year will have already had me as an instructor in physics 9, and may recall me discussing from time to time the "hidden curriculum" of that course, a lot of which has to do with *metacognition*—thinking about thinking. A parent of a recent student recognized what the "hidden curriculum" is about, and wrote this:

"Often people say, "Mr. Buszka teaches Physics." Some who know him a bit better say, "Mr. Buszka teaches you how to learn Physics." I would simply say "Mr. Buszka teaches you how to learn." Period. Physics happens to be the medium of choice (a good choice)."

(I'll do my best to live up to that description next year.)

Arons captures as well as anyone some of the principles of metacognition, so I thought his words would be good to have on your mind as we begin our year together. As you read, you may recall to mind occasions when you used (or would have been better off using!) the processes he writes about. You may recognize growth in yourself over the years. Perhaps these meditations will inspire you to do additional reading in this area, as they did for me.

E. Writing Assignment

After you have completed parts A-D above, please type up an essay about an aspect or aspects of the assignment that you found to be particularly thought-provoking.

Consider this essay to be opportunity for us to begin a conversation about learning physics. You might imagine this not as an obligation to complete, but more as an opportunity to explore some ideas in writing. Help me understand how your mind works. Show that you have thought deeply and well.

I think that no more than three pages, single-spaced, should be enough. I encourage you to include images if they can help explain your thinking.

If you have doubts about whether this or that essay topic would be appropriate, feel free to e-mail me. I'll check my e-mail most days during the summer.

Please upload a copy to the Summer Assignment post that I have created on Google Classroom. We'll be meeting on A days this term, so I put the due date as the first day of school: Thursday, Sept. 3.

I'm looking forward to welcoming you back to school in September. Have a happy summer.

13.2 A LIST OF PROCESSES

From Arnold Arons, *Teaching Introductory Physics*

To glimpse some of the ways in which effective schooling might enhance students' reasoning capacities, it is instructive to examine a few of the thinking and reasoning processes that underlie analysis and inquiry. These are processes that teachers rarely articulate or point out to students; yet these processes are implicit in many different studies. The following listing is meant to be illustrative; it is neither exhaustive nor prescriptive. Readers are invited to add or elaborate items they have identified for themselves or sense to be more immediately relevant in their own disciplines.

1. Consciously raising the questions "What do we know…? How do we know…? Why do we accept or believe…? What is the evidence for…?" when studying some body of material or approaching a problem.

Consider the assertion, which virtually every student and adult will make, that the moon shines by reflected sunlight. How many people are able to describe the simple evidence, available to anyone who can see, that leads to this conclusion (which was, incidentally, perfectly clear to the ancients)? This does not require esoteric intellectual skills; young children can follow and understand; all one need do is lead them to watch the locations of both the sun and moon, not just the moon alone, as a few days go by. Yet for the majority of our population the "fact" that the moon shines by reflected sunlight is received knowledge, not sustained by understanding.

Exactly the same must be said about the contention that the earth and planets revolve around the sun. The validation and acceptance of this view marked a major turning point in our intellectual history and in our collective view of man's place in the universe. Although the basis on which this view is held is more subtle and complex than that for the illumination of the moon, the "How do we know…?" should be an intrinsic part of general education; it is, for most people, however, received knowledge—as is also the view that matter is discrete in its structure rather than continuous.

Similar questions should be asked and addressed in other disciplines: How does the historian come to know how the Egyptians, or Babylonians, or Athenians lived? On what basis does the text make these assertions concerning the consequences of the revocation of the Edict of Nantes? What is the evidence for the claim that such and such tax and monetary policies promote economic stability? What was the basis for acceptance of the doctrine of separation of church and state in our political system?

Cognitive development researchers [e.g., Anderson (1980); Lawson (1982)] describe two principal classes of knowledge: figurative or declarative on the one hand, and operative or procedural on the other. Declarative knowledge consists of knowing "facts" (matter is composed of atoms and molecules; animals breathe oxygen and expel carbon dioxide; the United States entered the Second World War after the Japanese attack on Pearl Harbor in December 1941). Operative knowledge involves understanding where the declarative knowledge comes from or what underlies it (What is the evidence that the structure of matter is discrete rather than continuous? What do we mean by the terms "oxygen" and "carbon dioxide" and how do we recognize these as different substances? What worldwide political and economic events underlay the American declaration of war?). And operative knowledge also involves the capacity to use, apply, transform, or recognize the relevance of declarative knowledge in new situations.

"Above all things," says Alfred North Whitehead in a well-known passage on the first page of *The Aims of Education,*" we must beware of what I will call 'inert ideas'—that is to say, ideas that are merely received into the mind without being utilized, or tested, or thrown into fresh combinations." And John Gardner once deplored our tendency to "to hand our students the cut flowers while forbidding them to see the growing plants."

Preschool children almost always ask "How do we know…? Why do we believe…?" questions until formal education teaches them not to. Most high school and college students then have to be pushed, pulled, and cajoled into posing and examining such questions; they do not do so spontaneously. Rather, our usual pace of assignments and methods of testing all too frequently drive students into memorizing end results, rendering each development inert. Yet given time and encouragement, the habit of inquiry can be cultivated, the skill enhanced, and the satisfaction of understanding conveyed. The effect would be far more pronounced and development far more rapid if this demand were made deliberately and simultaneously in science, humanities, history, and social science courses rather than being left to occur sporadically, if at all, in one course or discipline.

2. Being clearly and explicitly aware of gaps in available information. Recognizing when a conclusion is reached or a decision made in absence of complete information and being able to tolerate the attendant ambiguity and uncertainty. Recognizing when one is taking something on faith without having examined the "How do we…? Why do we believe…?" questions.

Interesting investigations of cognitive skill and maturity are conducted by administering test questions or problems in which some necessary datum or bit of information has been deliberately omitted, and the question cannot be answered without securing the added information or making some plausible assumption that closes the gap. Most students and many mature adults perform very feebly on these tests. They have had little practice in such analytical thinking and fail to recognize, on their own, that information is missing. If they are told that this is the case, some will identify the gap on reexamining the problem, but many will still fail to make the specific identification.

In our subject matter courses, regardless of how carefully we try to examine evidence and validate our models and concepts, it will occasionally be necessary to ask students to take something on faith. This is a perfectly reasonable thing to do, but it should never be done without making students aware of what evidence is lacking and exactly what they are taking on faith. Without such care, they do not establish a frame of reference from which to judge their level of knowledge, and they fail to discriminate clearly those instances in which evidence has been provided from those in which it has not.

3. Discriminating between observation and inference, between established fact and subsequent conjecture.

Many students have great trouble making such discriminations even when the situation seems patently obvious to the teacher. They are unused to keeping track of the logical sequence, and they are frequently confused by technical jargon they have previously been exposed to but never clearly understood.

In the case of the source of illumination of the moon cited earlier, for example, students must be made explicitly conscious of the fact that they see the extent of illumination increasing steadily as the angular separation between moon and sun increases, up to full illumination at a separation of 180°. This direct observation leads, in turn, to the inference that what we are seeing is reflected sunlight.

In working up to the concept of "oxygen" (without any prior mention of this term at all) with a group of elementary school teachers some years ago, I had them do an experiment in which they heated red, metallic copper in an open crucible and weighed the crucible periodically. What they saw happening, of course, was the copper turning black and the weight of crucible and contents steadily increasing. When I walked around the laboratory and asked what they had observed so far, many answered, "We observed oxygen combining with the copper." When I quizzically inquired whether that was what they had actually seen happening, their reaction was one of puzzlement. It took a sequence of Socratic questioning to lead them to state what they had actually seen and to discern the inference that something from the air must be joining the copper to make the increasing amount of black material in the crucible. It had to be brought out explicitly that this "something from the air" was the substance to which we would eventually give the name "oxygen." What they wanted to do was to use the technical jargon they had acquired previously without having formed an awareness of what justified it.

This episode illustrates the importance of exposing students to repeated opportunity to discriminate between observation and inference. One remedial encounter in one subject matter context is not nearly enough, but opportunities are available at almost every turn. Mendel's observations of nearly integral ratios of population members having different color and size characteristics must be separated from inference of the existence of discrete elements controlling inheritance. In the study of literature, analysis of the structure of a novel or a poem must be distinguished from an interpretation of the work. In the study of history, primary historical data or information cited by the historian must be separated from the historian's interpretation of the data.

A powerful exercise once employed by some of my colleagues in history was to give the students a copy of the Code of Hammurabi accompanied by the assignment: "Write a short paper addressing the following question: From this code of laws, what can you infer about how these people lived and what they held to be of value?" This exercise obviously combines exposure to both processes 1 and 3.

4. Recognizing that words are symbols for ideas and not the ideas themselves. Recognizing the necessity of using only words of prior definition, rooted in shared experience, in forming a new definition and in avoiding being misled by technical jargon.

From the didactic manner in which concepts (particularly scientific concepts) are forced on students in early schooling, it is little wonder that they acquire almost no sense of the process of operational definition and that they come to view concepts as rigid, unchanging entities with only one absolute significance that the initiated automatically "know" and that the breathless student must acquire in one intuitive gulp. It comes as a revelation and a profound relief to many students when they are allowed to see that concepts evolve; that they go through a sequence of redefinition, sharpening, and refinement; that one starts at crude, initial, intuitive levels and, profiting from insights gained in successive applications, develops the concept to final sophistication.

In my own courses, I indicate from the first day that we will operate under the precept "idea first and name afterwards" and that scientific terms acquire meaning only through the description of shared experience in words of prior definition. When students try to exhibit erudition (or take refuge from questioning) by name dropping technical terms that have not yet been defined, I and my staff go completely blank and uncomprehending. Students catch on to this game quite quickly. They cease name dropping and begin to recognize, on their own, when they do not understand the meaning of a term. Then they start drifting in to tell us of instances in which they got into trouble in a psychology, or sociology, or economics, or political science course by asking for operational meaning of technical terms. It is interesting that this is an aspect of cognitive development to which many students break through relatively quickly and easily. Unfortunately, this is not true of most other modes of abstract logical reasoning.

5. Probing for assumptions (particularly the implicit, unarticulated assumptions) behind a line of reasoning.

In science courses, this is relatively easy to do. Idealizations, approximations, and simplifications lie close to the surface and are quite clearly articulated in most presentations. They are ignored or overlooked by the students, however, principally because explicit recognition and restatement are rarely, if ever, called for on tests or examinations. In history, humanities, and the social sciences, underlying assumptions are frequently more subtle and less clearly articulated; probing for them requires careful and self-conscious attention on the part of instructors and students.

6. Drawing inferences from data, observations, or other evidence and recognizing when firm inferences cannot be drawn. This subsumes a number of processes such as elementary syllogistic reasoning (e.g., dealing with basic prepositional, "if . . . then" statements), correlational reasoning, recognizing when relevant variables have or have not been controlled.

Separate from the analysis of another's line of reasoning is the formulation of one's own. "If. . . then" reasoning from data or information must be undertaken without prompting from an external "authority." One must be able to discern possible cause-and-effect relations in the face of statistical scatter and uncertainty. One must be aware that failure to control a significant variable vitiates the possibility of inferring a cause-and-effect relation. One must be able to discern when two alternative models, explanations, or interpretations are equally valid and cannot be discriminated on logical grounds alone.

As an illustration of the latter situation, I present a case I encounter very frequently in my own teaching. When students in a general education science course begin to respond to assignments leading them to watch events in the sky (diurnal changes in rising, setting, and elevation of the sun, waxing and waning of the moon, behavior of the stars and readily visible planets), they immediately expect these naked eye observations to allow them to "see" the "truth" they have received from authority, namely that the earth and planets revolve around the sun. When they first confront the fact that both the geo- and heliocentric models rationalize the observations equally well and that it is impossible to eliminate one in favor of the other on logical grounds at this level of observation, they are quite incredulous. They are shocked by the realization that either model might be selected provisionally on the basis of convenience, or of aesthetic or religious predilection. In their past experience, there has always been a pat answer. They have never been led to stand back and recognize that one must sometimes defer, either temporarily or permanently, to unresolvable alternatives. They have never had to wait patiently until sufficient information and evidence were accumulated to develop an answer to an important question; the answer has always been asserted (for the sake of "closure") *whether the evidence was at hand or not,* and the ability to discriminate decidability versus undecidability has never evolved.

An essentially parallel situation arises in the early stages of formation of the concepts of static electricity (see Sections 6.7 and 6.8). Students are very reluctant to accept the fact that, before we know anything about the microscopic constitution of matter and the role of electrical charge at that level, it is impossible to tell from observable (macroscopic) phenomena whether positive charge, negative charge, or both charges are mobile or being displaced. They wish to be told the "right answer" and fail to comprehend that any one of the three models accounts equally well for what we have observed and predicts equally well in new situations. They want to use the term "electron" even though they have no idea what it means or what evidence justifies it, and they apply it incorrectly to irrelevant and inappropriate situations.

If attention is explicitly given, experiences such as the ones just outlined can play a powerful role in opening student minds to spontaneous assessment of what they know and what they do not know, of what can be inferred at a given juncture and what cannot.

7. Performing hypothetico-deductive reasoning; that is, given a particular situation, applying relevant knowledge of principles and constraints and visualizing, in the abstract, the plausible outcomes that might result from various changes one can imagine to be imposed on the system.

Opportunities for such thinking abound in almost every course. Yet students are most frequently given very circumscribed questions that do not open the door to more imaginative hypothetico-deductive reasoning. The restricted situations are important and provide necessary exercises as starting points, but they should be followed by questions that impel the student to invent possible changes and pursue the plausible consequences.

8. Discriminating between inductive and deductive reasoning; that is, being aware when an argument is being made from the particular to the general or from the general to the particular.

The concepts of "electric circuit," "electric current," and "resistance" can be induced from very simple observations made with electric batteries and arrangements of flashlight bulbs. This leads to the *inductive* construction of a "model" of operation of an electric circuit. The model then forms the basis for *deductive* reasoning, that is, predictions of what will happen to brightness of bulbs in new configurations or when changes (such as short circuiting) are imposed on an existing configuration.

Exactly similar thinking can be developed in connection with economic models or processes. Hypothetico-deductive reasoning is intimately involved in virtually all such instances, but one should always be fully conscious of the distinction between the inductive and the deductive modes.

9. Testing one's own line of reasoning and conclusions for internal consistency and thus developing intellectual self-reliance.

The time is long past when we could teach our students all they need to know. The principal function of education—higher education in particular— must be to help individuals to their own intellectual feet: To give them conceptual starting points and an awareness of what it means to learn and understand something so that they can continue to read, study, and learn as need and opportunity arise, without perpetual formal instruction. To continue genuine learning on one's own (not just accumulating facts) requires the capacity to judge when understanding has been achieved and to draw conclusions and make inferences from acquired knowledge. Inferring, in turn, entails testing one's own thinking, and the results of such thinking, for correctness or at least for internal coherence and consistency. This is, of course, a very sophisticated level of intellectual activity, and students must first be made aware of the process and its importance. Then they need practice and help.

In science courses, they should be required to test and verify results and conclusions by checking that the results make sense in extreme or special cases that can be reasoned out simply and directly. They should be led to solve a problem in alternative ways when that is possible. Such thinking should be conducted in both quantitative and qualitative situations. In the humanities and social sciences, the checks for internal consistency are more subtle, but they are equally important and should be cultivated explicitly. Students should be helped to sense when they can be confident of the soundness, consistency, or plausibility of their own reasoning so that they can consciously dispense with the teacher and cease relying on someone else for the "right answer."

10. Developing self-consciousness concerning one's own thinking and reasoning processes.

This is perhaps the highest and most sophisticated reasoning skill, presupposing the others that have been listed. It involves standing back and recognizing the processes one is using, deliberately invoking those most appropriate to the given circumstances, and providing the basis for conscious transfer of reasoning methods from familiar to unfamiliar contexts.

Given such awareness, one can begin to penetrate new situations by asking oneself probing questions and constructing answers. Starting with artificial, idealized, oversimplified versions of the problem, one can gradually penetrate to more realistic and complex versions. In an important sense, this is the mechanism underlying independent research and investigation.