

Calculators are great!

Calculators are fantastic products of our electronic age –incredible time savers and convenience machines with remarkable capabilities far beyond what the most powerful computers could do not too long ago. I'm still not going to allow their use during exams, though, and in case your interested I am placing here a few words to let you know why. By doing so, I am not inviting debate about the calculator policy. I am doing so as a matter of information for your consideration –I welcome comments and stimulating, positive discussion about the philosophical issues. Yet the no-calculator policy will remain in place for the semester and therefore I urge you to prepare accordingly.

Some background first for context: I am a die-hard techno-nerd –I love the latest electronic toys, I usually own the latest; if not personally then I enjoy using them in the context of my professional research activities. That includes calculators and computers and cell phones (I can't seem to keep up with iPods), not to mention lasers and all sorts of cool electronic gadgets I get to use in research. I am a firm believer in the positive role of technology in modern society. Even my own research involves the very speculative but exciting high-tech idea of using ultracold atom transistors for quantum computing (ultracold atoms won CU scientists Carl Wieman and Eric Cornell a Nobel Prize in 2001). Thus I am hardly one to shy away from calculators or to denigrate their utility.

The exam calculator policy has to do with carrying out my responsibility to you, and to those that are likely to employ you. I have been teaching for 30 years, beginning at the University of Arizona, then Caltech, and since 1984 here at CU. I have a keen interest in being relevant to society and in that vein my job is to prepare students for their future careers. Since about 1996 I have been actively involved with surveying high-tech industries. What is it they want in a new employee fresh out of college? What do they see that is positive about the way we (CU) trains students, and what do they see that is negative? What are the most important skills that they look for? I am talking about all kinds of industry –big ones like IBM, Qwest, Ford Motor Company, Xerox and our own local Ball Aerospace Corporation, and small ones, most of which you will not have head of, including entrepreneurial ventures and businesses that are still based in someone's garage. What is remarkable is the unanimity among all companies about what is important: the list would surprise many of you. What might not be surprising is that which tops the list for technology-based companies is the personal characteristic “adept at problem solving”.

Years ago companies used to complain about students needing to be computer literate. Computer literacy is not a problem any more. These days there is an overwhelming recognition that students graduating from college and above have become increasingly weaker in basic skills over the years –basic skills meaning reading, writing, and, you guessed it, arithmetic; also higher level problem solving analytical and conceptualization skills. Moreover, I have had the opportunity to interview an awful lot of students over the years. What makes this person or that person successful seems to vary all over the map; there are very few characteristics that apply to all successful people. Yet among those in technical fields being adept at problem solving is just about universal. And the fact is, technology, in particular calculators and computers, never plays a central role in problem solving ability. What does play a central role is a high level of comfort and skill with the concepts relevant to the field at hand and almost always a high level of comfort and skill with numbers. While I am most familiar with the needs of technical companies, I have seen those very same skills in other arenas, in business for example, where a capable business person can make estimates of profit based on market size, product price, cost of manufacture, cost of packaging and distribution, interest on loans, and so on.

Industry is not the only one to recognize and feel the decline of basic analytical thinking skills. And I am not the only one who implements a no-calculator exam policy. Calculators, and more generally

computers, are recognized as tools that can be used to both promote and to impede learning. Educators in quality institutions everywhere in the US are struggling with the dichotomy especially as plagiarism and other forms of ethical violations seem to be on the increase. But in a much simpler vein having nothing to do with ethics, reliance on electronic machines as calculators is overwhelmingly identified as an impediment to learning and as an impediment to developing problem-solving skills. Even if you yourself had use of calculators throughout your high school and college career, that scene is beginning to change. More and more teachers are prohibiting the use of calculators during exams, even at the middle school and high school levels, as my daughters will attest.

What do I have to say to those of you who argue that physics is not math and you should not be forced to do so much math on a physics test and, furthermore, you say it impedes your learning of physics? It's true, physics is not math, and the physics tests are not meant to be a test of your math (actually arithmetic) skills per se. The physics exams are not meant to test your familiarity with English, either. But weakness in English usage can lead to difficulties with the exam (ask one for whom English is a second language), and likewise, weakness in math skills can lead to difficulties on the exam too. Arithmetic is a prerequisite for the class –you are expected to know math and be able to utilize those skills. I did see several students slowed during the exam by doing long division and working out multiplications to several significant figures. To those that find that they have done so, I urge you to hone your ability to make estimates. Realize that 42 is close enough for 7.25×5.8 , so are 40, 41, 43, and 44 for the exam purposes. Being able to estimate to a bit better than one significant figure is an enormously valuable time saving skill worth your time investment to acquire.

As you contemplate these words you should keep a couple of things in mind. You should know that for most of us, including me, numerical ability is a learned skill that atrophies with disuse. I understand and sympathize with many of you who truly struggle with math and with numbers. The best solution I know of is to practice using numbers often to hone your skills. Also know that as you pursue your career you will be competing against people who are just as smart and just as much wanting the job that you seek as you are. It will only be to your competitive and otherwise long-term advantage to cultivate your problem solving skills, in particular, beginning with your familiarity and ability with numbers as well as concepts. Quite apart from the competitive issue, it **will** enable you to be better at what you do. Moreover, it is very likely that someday you will be in a position to make personnel decisions. As you consider whom to choose among the job applicants for example, it is exceedingly likely that you will make your choice based in no small amount on a person's problem solving ability, whether they be a rocket scientist, a secretary, or a doctor you need to select to diagnose your sick child. Some of you might argue that utilizing a calculator on an exam has nothing to do with problem solving skills, but the evidence is much to the contrary, certainly in the technical domain.

While you are in Phys 1110 I hope that you can appreciate that my job is to prepare you in the best way possible for those institutions that will employ you based on your talents and ability to contribute to the objectives of the institution. It is also my job to assess your skills and abilities in the context of the course and part of that assessment involves your math skills. Attempting to assess in a fair manner I do on behalf of you as an individual, on behalf of the class as a whole, and also on the behalf of those institutions that will be thinking about hiring you.