From Faraday to artificial light, from Heisenberg to cancer detection –
From pure science to technological advances
Curriculum Development Grant Application, 2014
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Objectives and Significance of the Project:
The Department of Physics and Astronomy is seeking support for efforts to carry out an over-arching, global, improvement of several of our courses. This project aims at providing a more coordinated application oriented approach that aims to address several distinct and independent issues at the same time. These two problems are related but have different implications:

1. The first problem is a local one, with focus on the class room and driven by the goal to activate and engage students at a deeper level. This is concerned with providing a curriculum that not only conveys excitement about the achievements of science in general, and physics in particular, as illustrated by the fundamental discoveries described in these classes, but also by describing how exactly those pinnacles of the human mind have a dramatic impact on how we live in a technological society. This would also be in line with some of the views expressed on occasion about the role of the regional campuses in their communities. Furthermore it should help alleviate the impressions expressed by one student in the past, who noted that what is encountered in the introductory class is “stuff done by a lot of dead guys a long time ago”. It turns out that those “dead guys” are very much alive in the technology that we use today!

2. The second problem is global in nature, one that is encountered in our society at large, but also in our student body at every level. It is concerned with what I perceive as a lack of understanding of the key importance of basic research, as an enterprise whose initial impulse is completely decoupled from any application driven considerations, to the technological advances which benefit all the members of our society.

This lack of insight has implications all the way to the legislature where directives are formulated about which research should be funded and which should not.

Both of these problems could be addressed at the same time by providing insight into how discoveries made in fundamental research, made initially purely as curiosity driven explorations, can lead to technological applications that beggar the imagination not only of those who originally made these discoveries, but several generations after them. These applications improve the lives of billions of people on this planet, and sometimes they make the difference between life and death. The difficult thing to understand is that these applications could not have been foreseen
Recent political developments, as well as some informal probes I conducted in classes, indicate that there is a fundamental misconception of the origin of technological advances, by which I mean the most general conceivable advance, be that communication technology, medical tech, environmental tech, or any other technologies. An opinion that probably is wide-spread in the general population, and certainly common among our students, is that the essential technological tools that we rely on every minute of our lives have been invented by engineers. Nothing could be further from the truth, but this is difficult to appreciate because of an enormous time lag that separates the discoveries made in basic research and the technological application. This time lag is usually measured in decades and it is not uncommon to be of the order of a century. For this reason it is not at all easy to gain a historical perspective that is extensive enough to recognize that the origin of refrigerators goes back to fundamental basic research done almost 200 years ago, cars are based on research by now 150 years old, while computers are based on quantum mechanics, a theory invented 80 years. So are DVDs. Nuclear magnetic resonance is a medical technique based on post-quantum mechanics nuclear physics from the 1930s. The problem with all these technological advances is that not only were they not on the mind of the researchers doing the their fundamental discoveries, these trail blasers doing the basic research were often long dead by the time the technological application of fundamental principles took place. The main problem is time – it takes decades for fundamental physics research to find application.

The goal of this proposal is to construct modules that can be used in many quite different classes, starting from the introductory sequences PHY P201/202 and PHY P221/222, our modern physics sequence P301/302, as well as upper level classes such Electrodynamics PHY P331, Thermodynamics P340, and Quantum Mechanics PHY P453. These modules are to describe coherent stories that illustrate for certain gadgets important today the whole development, starting from the original discovery of the basic physical principles to the final product that we use today. This is not so easy because these developments do have a long and usually complicated history. I’ve been wanting to write such modules for some time now, but I have never had the time to actually research the history in sufficient detail to be able to distill the key steps into a sufficiently coherent summary, not to mention write anything up. I have thought for several years now that I should do this while teaching the corresponding classes, but the years go by and there are always too many other demands that gobble up too much time to make progress with this idea. One of triggers that suggested to me that it is important to think at a deeper level about applications is a comment by a student in the introductory physics sequence to the effect that we’re discussing in these classes ”old stuff that was invented by a lot of dead guys a long time ago”. While it is
true that the principles of these intro classes were discovered a long time ago, these "dead guys" are very much alive today in a great many gadgets we use. And in fact our lives would not at all be the same without them. It is this fact that I would like to convey to our students in a more immediate and dramatic way. My hope is that after they graduate their better appreciation of fundamental science will diffuse and spread. All the way to were it matters.

**Planned activities:**

The main product of this project will be several modules to be made available to all members of the physics department and to be used in at least 10 of our classes, both introductory and upper level, including electives (listed above, P201/202, P221/222, P301/302, P331, P340, P453 and S405). There are several examples that I have in mind, ranging from the mundane to the profound and from the amusing to the life preserving. I’m sure that once I start thinking about this in earnest many other examples will come to my mind, but a brief selection of modules that would be possible are the following:

1. Artificial light, as an application of several strands, but beginning with Faraday, an une-ducated book binder in the early 19th century, and ending with Edison a life time later. Somewhere in there is a fascinating story about a feud between Tesla and Edison that seems relevant for today’s technology, but which I’ve never had time to sort out.

2. Engines, as applications of mechanics, thermodynamics, and electricity, topics that are taught at the introductory level in P201, P221 and in the upper level electrodynamics class P441.

3. Refrigeration systems, as an application of both electrodynamics and thermodynamics, with electrodynamics a topic of three of our classes, P202, P222 and P331.

4. Computers, as an application of quantum mechanics, a topic that arises in our modern physics sequence P301 and P302, as well as the quantum mechanics class P453.

5. DVDs, as a quite recent application of quantum mechanics that is younger in fact than all of our current students.

6. NMR, as a medical technique that is an outgrowth not only of nuclear physics, but also particle physics.

7. GPS as an application of general relativity.

8. The web browser, as an outgrowth, suprisingly, of particle physics.
For the above modules I have at present some vague idea how the link could go between original discoveries and technological tool many decade downtime. I have also contemplated more recent developments for which I do not really know enough even in principle whether it is possible to construct a module, but one of the things I have in mind is to construct a module that would be of interest for our introductory Astronomy N190 classes. Many of these students take this class as their exposure to a natural science and it would be particularly important to reach this part of our student population. A starting point in this direction would be to see whether certain optical techniques developed purely for the purpose of detecting a black hole at the center of our Milkyway have yet given rise to technological applications that have entered mainstream.

Qualifications of the instructor:
Since coming to IUSB I have taught almost all the physics courses we offer, including the introductory astronomy. I have introduced a new upper level elective course into the IU curriculum and I’m in the process of introducing a second one. Another innovative course that I have taught is the differential geometry class M435 with a rather novel content, going beyond the usual curriculum by aiming at the geometric concepts necessary to understand Einstein’s theory of general relativity, including a discussion of Einstein’s equations, black holes, and cosmology.

I’ve put much effort into revamping the upper level courses, and I’ve begun to write manuscripts to counter the horrific textbook wasteland that one encounters for these courses. I started with latexed notes for Electrodynamics (P331, 140 pages), Analytical Mechanics (P441, 330 pages) and Quantum Mechanics (P453, 300 pages). I have also written some notes for some of the upper level elective course I have taught, for example Relativistic Quantum Theory (S405-11, 370 pages), and most recently General Relativity (S405-13, 1000 pages). The development and writing of these notes is part of the reason why hardly any time is left for anything else because most semesters I teach the intro sequence with labs and recitation, as well as an upper level or elective course. This eats up all the time and energy I have.

The project proposed here does not seem to have precedents. I have had an interest in modernizing the curriculum for some time now. In order to get an idea of what ideas are currently under discussion I have attended a Winter meeting of the American Associated of Physics Teachers. I also have researched other more sweeping changes of the upper level undergraduate programs, such as the Paradigms in Physics program at Oregon State University at Corvallis, OR, described in refs. [1,2,3]. The origin of the paradigm program is quite different from the difficulties that the present proposal aims to address, and I believe that the attempt made at Oregon State University to improve the upper level of the physics undergraduate curriculum is mired in what is known as cooking recipe instruction, and is in fact detrimental to a deeper conceptual and practical
understanding of physics. My reading of the final report on the Paradigm Project at OSU is that it was not perceived as successful by the local evaluator [4].

I have received previously a Curriculum Development Grant many years ago in 2007 and some Faculty Research Grants between 2005 and 2009. The latter have led to a number of published papers and also an NSF funded grant (2010–2013), for which I was the PI (with Monika Lynker as Co-PI). The CDG in 2007 had a very different focus, having been aimed solely at the improvement of some of our upper level courses. The reach of the present proposal is much broader, both vertically as well as horizontally.

I received the IUSB Educator of the Year Award in 2011 from the SGA and in 2013 I was awarded a Trustee’s Teaching Award.

**Efforts to Obtain Additional Funding:**
Once the modules have been written the main effort will be in tweaking them so that they adjust to the emerging needs of the various classes. This effort will only need resources from within the department, mostly the involvement of the faculty. If this modernization of the physics (and potentially astronomy) curriculum should prove of interest more generally, I could envision writing an NSF CLLI proposal to support further development of this idea and to write a how-did-it-happen? book with the above philosophy in mind.

**References:**


**BUDGET:**

As in my previous curriculum development proposal from 2007, I’m requesting support for a course release (for the Fall of 2014). This has been arranged with our chair Henry Scott.

**Support for a course release:** $3000