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## Rationale for Modern Physics to be an Associate Degree Capstone Course

The first two semesters of physics teach Newtonian mechanics and electromagnetism. While equipping students with basic science and mathematical skills, these courses cover physics up to the $19^{th}$ century. This means that students who only take the first two physics courses (which is the majority of students) miss out on all of the exciting developments of $20^{th}$ century physics, including Relativity, black holes, quantum mechanics, and the study of the beginning of the universe itself. These students certainly will not be exposed to the physics of the early $21^{st}$ century, such as the production of the thinnest substance in existence and the discovery of the Higgs Boson.

This is the way that it is done at all universities, and for good reason: it is impossible to understand the exciting more recent developments without using the skills and techniques that are taught in the first two semesters of physics as well as mathematics. In fact, in most universities, even the third semester of physics only takes students up to the early $20^{th}$ century with a rather convoluted study and interpretation of the mixed bag of observations that eventually paved the way to quantum mechanics.

Our Modern Physics course has been specifically designed to provide our students with an overview of "all the good stuff" in a single semester. We have divided the lectures into three portions, with each one being taught by an expert actively involved in the current developments of that subfield. For my part, I cover the special and general theories of relativity, black holes and cosmology. Much thought has gone into finding the optimal way to present this material-- much of it normally reserved for graduate students-- in such a way that it can be understood with the knowledge garnered from only two semesters of physics. For example, solving the Einstein equation normally requires a working knowledge of differential geometry, which is calculus on curved spacetime manifolds. I present a limited version of this in such a way that the students can solve the associated differential equations and obtain solutions that describe black holes as well as the expansion of the universe itself. This enables them to feel the excitement of actually doing hands-on calculations with the Einstein equation while still using similar types of differential equations that are used in the first two semesters of physics to describe Newton's second law of motion and electromagnetism.

In a similar manner, Prof. Oleg Berman uses the quantum description of atoms to show how the thinnest substance in the world was recently constructed. Prof. Giovanni Ossola shows how machines as large as cities are being used to find the smallest building blocks of everything. Prof. Roman Kezerashvili has complemented these lectures by designing new laboratory experiments which enable students to perform the actual experiment associated with Einstein winning the Nobel prize, to see for themselves how quantum mechanics gives rise to lasers, and to simulate the greatest mystery of modern-day science known as Dark Matter. After two years of running, this course is already building a track record for inspiring students to pursue a Bachelor's degree in physics.

Normally it might be artificial to integrate elements of writing, effective speaking and the philosophy of ethics within an advanced physics course such as this, whose aim is to teach the mathematical description of physical phenomena and problem-solving skills. Likewise, an English course should not be expected to teach mathematical problem-solving skills and one would hardly take a course on music theory with the hope of learning about ethics. Having said that, we have designed Modern Physics such that it provides all of the above, thereby providing an invaluable Associate Capstone experience regardless of the future plans of the students.

During the course of the semester, students hand in approximately 120 pages of technical writing in the form of laboratory reports that include detailed sections on objectives, background material, analysis and interpretation, and conclusions. This provides them with a tremendous amount of practice, and week-by-week instructor feedback, on their technical writing skills. It involves them performing measurements and data analysis with a computer interfaced with detectors, and then using Excel and Microsoft Word to write the reports. The students practice their effective oral communication skills by presenting a research project to the class, which involves them making PowerPoint slides. Since this course includes a section on nuclear physics, it even provides us with the unique opportunity of engaging our students in a technical discussion on the ethics and science policy pertaining to the production and regulations of nuclear resources.

I believe that for a one-semester course, this is the optimal combination of components that teaches not only analytical skills for physics and mathematics but also technical writing and effective speaking skills while even offering an ethical component.

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