Physics 100: The First-Year Seminar in Physics

Accelerator-Based Materials Analysis to The Quark Structure of Matter

The course is divided into five two-week parts, with five different professors presenting background material in their field of expertise. We hope to make some connections between the material across these different topics and the professors will be coordinating the grading and logistics of the course. Here's an outline of the course:

1. **Accelerator-Based Materials Analysis:** PIXE, or Proton Induced X-ray Emission, is a powerful analytical tool for determining the elemental composition of a sample. PIXE is a relatively inexpensive and non-destructive analysis technique that is used routinely in research and industry. In order to use PIXE, a proton beam needs to be established and this is done using a particle accelerator. A 1.1 million volt Pelletron particle accelerator will be used to create a beam of 2.2 million electron volt protons that will interact with the atoms that make-up the unknown sample. X rays characteristic of the elements in that sample will be produced from interactions between the protons and the inner shell electrons. The characteristic x-ray energy spectrum will be recorded and analyzed to identify the elemental composition. (Scott LaBrake)

2. **Monte-Carlo Methods in Physics:** The Monte-Carlo method is a kind of calculation in which computer-generated random numbers are used, often in unexpected ways. The method is used widely in both theoretical and experimental physics. Sometimes it is used to simulate truly random processes like radioactive decay, and sometimes it is used in more subtle ways to simulate processes that are merely similar random processes. You will learn elements of programming and use Monte-Carlo methods to address several physics-related problems. (Gary Reich)

3. **Lasers:** Lasers are found in lots of everyday technology today, from the supermarket checkout to your CD player. We'll first learn a bit about the physical properties of light, in general, and laser light, in particular. After learning about how lasers work, we'll see some of their applications in industry, medicine, and science, as well as their use as a tool in the study of the structure and dynamics of biomolecules. (Jay Newman)

4. **Laser Cooling:** We will explain how to cool a sample of atoms to a temperature of only a few millionths of a degree above absolute zero using nothing but light from a laser. We will study the basic techniques of laser cooling and atom trapping (Doppler cooling, "optical molasses," and magnetic trapping), and applications of these techniques ranging from the building of laser-cooled atomic clocks to the study of exotic quantum mechanical phenomena like Bose-Einstein Condensation. (Chad Orzel)

5. **Quark Structure of Matter:** The atomic nucleus is at the heart of all matter. Lying at the core of every atom and comprising over 99% of its mass, the nucleus is made up of protons and neutrons. The protons and neutrons, collectively referred to as nucleons, are in turn made up of what we now believe are the fundamental constituents of matter, called quarks. In this

module we'll discuss our current understanding of nuclear structure and the experiments that led to this understanding. We will also talk about the very active research going on today to try to understand how the quark model accounts for the observed properties of nuclei. (Mike Vineyard)

Reading material will be supplied for each modular topic as will homework assignments. The nature of the homework may vary with the module, but there will be some graded work for each two-week portion of the course. Students are *encouraged to work on the assignments together with others in the course.* It is expected, however, that the *work you hand in to be graded will be written up independently by you* after discussions with other students. **Please indicate on the homework who you worked with in preparing the assignment.**

Each module will also have an associated take-home quiz, lab, or project. Although the quizzes are take-home, they should be limited to a single hour period of time. Find a quiet location and work on the quiz alone, without other materials, in a one hour time of your choosing.

Finally, your grade will be determined by the quizzes/projects (60%) and the homework (40%). The instructors will feel free to treat the percentages as being guidelines and not as being rigid and fixed.