Syllabus of PHY445/515

The goal of this course is to provide students with experience in the scientific method specifically including: statistical and systematic analysis of data in comparison to theory; hands-on experience in a variety of modern experimental techniques; and presentation of experimental results at a professional level. Students must choose experiments in each of three major areas. The experiments currently available are listed here.

**Atomic, Molecular and Optical Physics**

**Diode Laser Saturation Spectroscopy:** Measure the Doppler broadened absorption spectrum of atomic Rb (5s-5p) using a tunable diode laser. Then, use saturation spectroscopy to measure the Doppler free spectrum which allows one to resolve the hyperfine structure of both the ground and excited states.

**Magnetic Resonance and Optical Pumping:** Use optical pumping and magnetic resonance to measure the Zeeman splitting of energy levels in atomic Rb. Study the low and high field regimes and measure the earth's magnetic field.

**X-Ray Diffraction:** Use X-ray diffraction to measure the lattice spacing of several crystalline materials using characteristic X-Ray lines from a copper target. Make a measurement of Planck's constant using Bremsstrahlung X-Rays.

**X-Ray Fluorescence and Mosley's Law:** Use x-ray fluorescence to measure the energies of inner shell transitions in an array of samples. This allows one to test Mosley's law and to identify unknown samples.

**Semi-Classical and Quantum Chaos:** Map out the modes of a 2D electromagnetic cavity. Determine the mode statistics for various cavity configurations.

**Condensed Matter Physics**

**The Hall Effect:** You will study the Hall effect in a two-dimensional electron gas and determine microscopic physical parameters of the system (such as the type, density, and mobility of the charge carriers).

**Nuclear Magnetic Resonance:** Learn the basics of NMR by using pulsed NMR to observe the resonance conditions and decay times in liquids and solids.

**Superconductivity:** Superconductivity occurs when normal electrons begin condensing into superconducting pairs, creating a superconducting gap in the electron energy spectrum. You will use tunnel junctions with Nb electrodes to study the DC Josephson effect and properties of superconducting Nb.
Second Order Phase Transitions: Measure the temperature dependence of the dielectric properties of a ferroelectric material and the magnetic susceptibility of a ferromagnet. Follow the transition from the low temperature (ordered) state to the high temperature (disordered) state.

Nuclear and Particle Physics

The Compton Effect: Measure the angular dependence of the differential scattering cross section for gamma-ray photons incident on free electrons and verify the wave-particle duality predicted by quantum mechanics (Klein-Nishina cross section).

The Gamma-Gamma Angular Correlation: Measure the angular correlation of the gamma rays emitted by $^{60}$Co nuclei and use this correlation to determine the sequence of spins of the $^{60}$Ni nuclei involved in the decay chain.

The Muon Lifetime: Measure the lifetime of the free $\mu^+$ lepton and the lifetime of the $\mu^-$ in matter.

Mössbauer Spectroscopy: Use recoilless emission and absorption to obtain a resolution of one part in $10^{11}$ of the 14.4 keV gamma ray in $^{57}$Co decay. Measure the isomer shift, magnetic field and electric quadrupole field gradient at the resulting $^{57}$Fe nuclei.

Van de Graaff – $^{11}$C Lifetime: Use the Van de Graaff accelerator to make $^{11}$C nuclei and measure their lifetime.

Learning Outcomes for PHY445 and PHY515:
Students who have completed PHY445/515
- should be able to perform basic experiments in physics,
- should be able to perform a statistical and systematic analysis of experimental data,
- should be able to write the results of an experiment in the style of a scientific paper.