Abstracts of Experiments in Experimental Physics Course (PHYS 2350)

1. Magnetic Moment
   In the Magnetic Moment experiment, the TEACHSPIN Magnetic Torque apparatus is used to measure the magnetic moment of a small permanent magnet embedded within a plastic cue ball in four different ways:
   - Static magnetic torque
   - Harmonic oscillation
   - Precession and
   - Net force in a magnetic field gradient

   You will also measure the magnetic moment using Hook's Law to measure the attractive force between the embedded magnet and an external magnetic field
2. Compton Scattering
   This experiment will recreate the famous Compton effect discovered by A.H. Compton in 1927. Compton scattering is the inelastic scattering of a high-energy photons (γ-ray) usually by an electron. A source of γ-rays will be used and the scattered medium energy photons from an aluminum rod will be detected by a NaI scintillator placed at various angles. The rest mass of an electron and the differential cross-section of the process will be measured from this experiment.
3. Earth Field NMR
   When an object with angular momentum is exposed to an external torque, it will tend to precess around the axis of that torque if displaced from the axial direction of the torque. The EF-NMR apparatus exposes water molecules in a sample to a field that misaligns them from earth's field, and after this field is removed, the molecules' precession causes a rotating magnetic field which induces a voltage in the pickup coils, and that is used to measure their frequency. The protons in the nuclei of the hydrogen atoms of water molecules contribute in this way to the overall magnetic moment of water molecules, allowing water molecules to experience a torque and align with an applied magnetic field. The apparatus from TEACHSPIN will enable the measurement of the spin-lattice relaxation time and the demonstration of Curie's Law. The effects of ionic solutions on the spin-lattice relaxation time will be explored.
4. Faraday Rotation (under both AC/DC Magnetic Fields)
   Michael Faraday discovered Faraday rotation in 1845 during an experiment in which he exposed lead glass to a magnetic field, observing that the presence of the magnetic field caused a rotation in polarized light after passing through the medium. The effect has since been observed in a range of materials, including water. For a given wavelength of light, the constant of proportionality between the strength of the magnetic field and the rotation of polarized light is called the Verdet constant, which can be measured and compared to a literature value. Here the Verdet constant of a glass rod will be measured when immersed in a DC magnetic field and an AC magnetic field using a polarized He-Ne laser beam. A comparison of measurements in both EM fields will be made. The Verdet constant of a different glass rod will be measured using the AC Magnetic Field approach.

5. Optical Pumping (Rubidium atom)
   The goal of the Optical Pumping Experiment is to show how a cell filled with two Rubidium gas isotopes (^{87}Rb and ^{85}Rb) absorbs light of specific wavelengths in response to temperature and a quasi static or time-varying (RF) magnetic fields. The energy levels of atoms that are available for optical transitions are affected by the following interactions: Electron spin-orbital interaction, electron-nuclear spin interaction and the interaction of spins with an external magnetic field which effect the absorptivity of the incident mono-energetic photons. The energy levels will be different for the two isotopes and demonstrated by varying the external magnetic field. The TEACHSPIN apparatus will enable the exploration of these effects in addition to measurements of the ratio between the g-factors of the isotopes. The transient effects of a single RF Resonance will be studied by turning the RF field on and off.
6. Analog Computing
   An analog computer will be developed from first principles using the operational amplifier as the fundamental building block. You will work with operational amplifiers in the electronic lab at the beginning of this course. As the computer is developed, one is able to integrate differential equations that describe a simple harmonic oscillator and a damped harmonic oscillator. You will also demonstrate the creation of beats as a result of an additional sinusoidal drive term in the differential equation.
7. Johnson Noise
   Charge is quantized because electrons are quantized. Johnson noise comes from the thermal fluctuations of electrons in matter. As the motion of electrons in matter change as a function of temperature, they induce currents. If the temperature of a resistor is changed, the electrons in the resistor would cause a fluctuation in current and produce a voltage difference across the resistor. In this lab you will measure these fluctuations of voltage across several resistors at a fixed temperature (Room Temperature) in order to determine the Boltzmann constant, k_B. The work horse for performing these measurements will be the operational amplifier which when designed properly will amplify Johnson noise to a level that one could measure on an oscilloscope. You will use the TEACHSPIN hardware that has been appropriately configured to perform the same measurement and compare the results.
8. Hall effect
   The Hall effect experiment is an important diagnostic to determine the type of charge carriers in a sample together with important microscopic charge transport parameters in metals or doped semiconductors. By measuring the Hall voltage, using hardware that contains a doped germanium crystal, three parameters (sample current, magnetic field and sample temperature) are systematically varied, one is able to extract the sample resistivity, the density and mobility of the charge carriers and determine the Hall coefficient. You will investigate the transition from extrinsic to intrinsic conductivity for the p-doped germanium sample and develop a functional form for the data.

9. Muon Physics

The muon is one of nature's fundamental "building blocks of matter" and acts in many ways as if it were an unstable heavy electron, for reasons no one fully understands. The instrument described in the Muon Physics Instructions document permits you to measure the charge averaged mean muon lifetime in a plastic scintillator and to demonstrate the time dilation effect of special relativity. The active volume of the detector is in the shape of a right circular cylinder made from transparent organic material. A charged particle passing through the scintillator will lose some of its kinetic energy by ionization and atomic excitation of the solvent molecules. Some of this deposited energy is then transferred to the fluor molecules whose electrons are then promoted to excited states. Upon radiative de-excitation, light in the blue and near-UV portion of the electromagnetic spectrum is emitted with a typical decay time of a few nanoseconds. A typical photon yield for a plastic scintillator is 1 optical photon emitted per 100 eV of deposited energy. To measure the muon's lifetime, we are interested in only those muons that enter, slow, stop and then decay inside the plastic scintillator. Such muons have a total energy of only about 160 MeV as they enter the tube. As a muon slows to a stop, the excited scintillator emits light that is detected by a photomultiplier tube (PMT), eventually producing a logic signal that triggers a timing clock.

10. Magnetic Levitation

The key realization for diamagnetic substances, is that the energy of a diamagnet depends upon the magnitude of the magnetic field, rather than the individual vector components. For traditional ferro/paramagnets, there can exist no field maxima in free space, there can however exist local minima of the field magnitude. As diamagnets repel areas of high magnetic field magnitude, they are attracted to these field minima, and may remain there in a static configuration.

This experiment aims to construct a modified version of the simple diamagnetic levitation instrument. In this configuration, a large powerful magnet suspended above the instrument is used to create a nearly uniform field region between two bismuth plates, this field serves to counteract the gravitational forces acting on a small magnet located between the plates. With the gravitational force nullified, the magnet is free to sit in the stable equilibrium arising from the repulsive bismuth ingots. The proposed instrument by the addition of a mg sensitive scale can measure apparent mass differences of the larger g-field canceling magnet. The ability to tune the inter-plate spacing is also a necessary modification.