THE EXPERIMENTS

Experiment 30a: Gamma Ray Interactions

This experiment provides a thorough introduction to the detection and spectral analysis of high-energy photons using a scintillator and multichannel analyzer. You will learn a bit about the nuclear process of beta decay, and will begin to understand how high-energy photons can interact with atoms. A result of your analysis will include an accurate measurement of the rest energy of the electron. ***You are required to complete this experiment before attempting any of the others.***

http://www.sophphx.caltech.edu/Physics_7/Experiment_30a_and_30b.pdf

Experiment 12: Electron Diffraction

The discovery of the wave-like nature of electrons by the American physicists Davisson and Germer in 1927 and by G. P. Thompson in 1928 earned Louis de Broglie, the theorist who proposed this idea, the 1929 Nobel Prize; Davisson and Thompson later shared the 1937 prize for those experiments. Our experiment, similar to Thompson's, examines the quite spectacular diffraction of electrons by crystals of graphite and aluminum, providing a precise determination of Planck's constant. ***You may not repeat this experiment if you performed it in Physics 6.***
http://www.sophphx.caltech.edu/Physics_7/Experiment_12.pdf

Experiment 13: The Solid State Diode

The PN junction semiconductor diode is a staple of modern electronics. The condensed matter theory describing its behavior is relatively modern, fascinating, and rich in detail. Understanding how the diode works requires a synthesis of facts from electromagnetism, statistical mechanics, and multi-particle quantum theory. This experiment investigates the accuracy of a simplified version of William Shockley's 1950 theory of the ideal PN junction diode (Shockley shared the 1956 Nobel Prize with J. Bardeen and W. Brattain for their invention of the transistor). ***You may not repeat this experiment if you performed it in Physics 6.***
http://www.sophphx.caltech.edu/Physics_7/Experiment_13.pdf

Experiment 20: The Geiger-Müller Detector and Ion Mobility

The Geiger-Müller tube, invented by members of Ernest Rutherford's UK group of researchers, was one of the world's first efficient detectors of high-energy particles. By studying the detailed shapes of its output pulses, you will investigate the surprisingly complex dynamics of ion drift in response to the intense electric field applied to the gas within the device.
http://www.sophphx.caltech.edu/Physics_7/Experiment_20.pdf

Experiment 21: A Beta Spectrometer and Relativity

The beta decays of radioactive ^{137}Cs nuclei produce high-energy electrons with a wide range of kinetic energies. By using an adjustable magnetic "lens" to select for electron momentum and a PIN diode detector to determine kinetic energy, you can measure the momentum-energy relationship of the electron and compare your results to the predictions of Newtonian and relativistic mechanics.
http://www.sophphx.caltech.edu/Physics_7/Experiment_21.pdf

Experiment 24: The Temperature Dependence of Resistance

Good conductors have a resistance which is very nearly proportional to temperature — why is that? Pure semiconductor materials, on the other hand, have a resistance which decreases exponentially with increasing temperature — again, why? As with the behavior of the PN junction diode (Experiment 13), the answers lie deep in the complex and subtle behaviors of the outer (valence) electrons of the atoms in the solid. This experiment tests some basic but important models derived from condensed matter theory, which synthesizes basic laws of electrodynamics, statistical mechanics, and quantum theory. ***You may not repeat this experiment if you performed it in Physics 6.***
http://www.sophphx.caltech.edu/Physics_7/Experiment_24.pdf

Experiment 25: The Balmer Lines of Hydrogen and Deuterium

Using a high-quality, research-grade spectrometer to accurately measure the emission line spectrum of a high-temperature mixture of hydrogen and deuterium gasses, you can accurately determine the difference between the wavelengths of the Balmer lines of hydrogen and the corresponding lines emitted by deuterium (^{2}H). These wavelength shifts are caused by the change in the reduced mass of the electron-proton v. electron-deuteron systems. You will use your data to determine the proton/electron mass ratio. You especially might like to perform this experiment if you did Experiment 25a during Physics 6, but that is not required.
http://www.sophphx.caltech.edu/Physics_7/Experiment_25.pdf

Experiment 27: The Normal Zeeman Effect

The presence of an external magnetic field causes the individual spectral lines emitted by a hot gas to split, although the splitting may be very small. This phenomenon is called the *Zeeman Effect* after the physicist who first observed it around 1896. A model for the source of the splitting was first proposed by Lorentz, who shared the 1902 Nobel Prize with Zeeman. Your careful measurements of the line splitting as a function of magnetic field strength will provide an accurate estimate of the electron's charge/mass ratio. ***You may not repeat this experiment if you performed it in Physics 6.***

http://www.sophphx.caltech.edu/Physics_7/Experiment_27.pdf

Experiment 28: The Mössbauer Effect

An atom whose nucleus emits a gamma ray must recoil to conserve linear momentum. The energy lost to the recoiling atom reduces the gamma ray energy enough to prohibit it from absorption by another, idential nucleus. While still a graduate student, Rudolph Mössbauer demonstrated that "recoilless" emission of gamma photons could occur from nuclei embedded in a crystal, allowing their subsequent absorption by identical nuclei. Mössbauer shared the 1961 Nobel Prize for this discovery. You will use this *Mössbauer Effect* to measure the absorption line profile of the 14.4keV gamma photon of ^{57}Fe, an "oscillator" with a quality factor Q of $\sim 10^{12}$.

http://www.sophphx.caltech.edu/Physics_7/Experiment_28.pdf

Experiment 29: The Mössbauer Effect – hyperfine splitting

The ambient magnetic field experienced by a nucleus in a ferromagnetic material such as iron will cause slight shifts in the nuclear energy levels through the Zeeman Effect. These tiny shifts are detectable using the highly sensitive technique of *Mössbauer Spectroscopy*. You will acquire the ^{57}Fe gamma photon absorption spectra of a few sample materials using a commercial spectrometer along with a relatively powerful radioactive source. ***Experiment 28 is a prerequisite for this experiment***.

http://www.sophphx.caltech.edu/Physics_7/Experiment_29.pdf

Experiment 30b: More Gamma Ray Interactions

This experiment will continue your investigation of the interactions of high-energy photons with atoms. You will look in detail at Compton scattering and electron-positron pair production within scintillation detectors. Your pair production spectrum will provide another means to estimate the electron rest energy.

http://www.sophphx.caltech.edu/Physics_7/Experiment_30a_and_30b.pdf

Experiment 31: Gamma Ray Absorption in Matter

By investigating the attenuation of a beam of high-energy photons (produced from the decay of ^{137}Cs) by various metals as a function of thickness, you will become familiar with the concept of the mean free path of a particle passing through an array of scattering sites. You will then appreciate how the number density of electrons within a solid plays a dominant role in determining its effectiveness as a shield against high-energy photons (x-rays and gamma rays).
http://www.sophphx.caltech.edu/Physics_7/Experiment_31.pdf

Experiment 32a: Compton Scattering – kinematics

The American physicist Arthur Compton's Nobel Prize-winning experiments of 1922 conclusively demonstrated the particle nature of high-energy photons. In our experiment high-energy photons from the decay of ^{137}Cs collide with valence electrons in a plastic scintillator; another scintillator is used to detect outgoing photons from the collisions which emerge at a specific angle (selected by the experimenter). The electronics looks for coincident detections by the two scintillators and records the energy deposited in each. You will use this data to examine the relativistic kinematics (4-momentum conservation) of the photon-electron collision process described by the *Compton Effect*.
http://www.sophphx.caltech.edu/Physics_7/Experiment_32.pdf

Experiment 32b: Compton Scattering – dynamics

Using the same apparatus as for Experiment 32a, you will further examine the nature of photon-electron scattering by measuring the rate of scattering into various angles. This rate depends on the *dynamics* of the collision process: the electromagnetic interaction between the two particles. You will use your results to test one of the first major theoretical results of quantum electrodynamics, the Klein-Nishina equation, presented in a paper of 1928 by Oskar Klein (Sweden) and Yoshio Nishina (Japan). ***Experiment 32a is a prerequisite for this experiment***.
http://www.sophphx.caltech.edu/Physics_7/Experiment_32.pdf

Experiment 33: The Stern-Gerlach Experiment

In our version of the famous 1922 experiment of the German physicists Otto Stern and Walther Gerlach, you will observe the quantization of a vector component of the magnetic moment of the electron and measure the value of the *Bohr magneton*. A beam of neutral potassium atoms is deflected by an applied non-uniform magnetic field; the deflection of each potassium atom in the beam is determined by its velocity as it enters the field and by its net magnetic moment (which is dominated by its single valence electron's inherent angular momentum, or *spin*).
http://www.sophphx.caltech.edu/Physics_7/Experiment_33.pdf

Experiment 34: Lifetime of a Nuclear Excited State

Beta decay of ^{57}Co results in a ^{57}Fe daughter nucleus which is an excited state. This state often decays to an intermediate state by emitting a 122keV photon, followed by a 14.4keV photon as this second nuclear state decays to the ^{57}Fe ground state. By measuring the statistics of the time intervals between the emissions of these two gamma photons you may accurately determine the lifetime of this 14.4keV excited state, which is less than 100nsec.

http://www.sophphx.caltech.edu/Physics_7/Experiment_34.pdf