Lab 5: Energy quantization in matter revealed in light

Experiment 1: Atomic Spectra

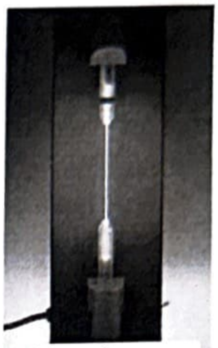

Figure 1
Discharge Lamp

Goal: Using the spectra emitted from a discharge lamp containing hydrogen, as in Figure 1, the Rydberg constant will be measured. The Ocean Optics spectrometer can be used to measure various wavelengths λ in the emission spectra. Be sure to record the width of the spectral lines as well, as they will be used to calculate the error in $1/\lambda$.

Experiment 2: Light-emitting diode (LED)

Goal: By measuring the voltage V at which the light-emitting diode turns on and the wavelength of light λ emitted, the constant e/hc can be measured, using the following relationship:

$$eV = hc/\lambda,$$

where h is Planck's constant, c is the speed of light, and e is the elementary charge of the electron.

An LED is solid state consisting primarily of a p-n junction; see http://hyperphysics.phy-astr.gsu.edu/hbase/Solids/pnjun2.html and http://hyperphysics.phy-astr.gsu.edu/hbase/Electronic/led.html. Without an externally applied voltage, a diffusion potential V_d is generated in the depletion layer between the n-type material, in which there are free electrons in the conduction band, and the p-type material, in which there are free "holes" in the valence band. The energy difference between the valence and conduction band E_g is very close to eV_d. The diffusion potential prevents electrons and holes from leaving the n- and p-regions and entering the opposite regions. When a bias voltage V is applied close to V_d the potential barrier is reduced to nearly zero and electrons can flow freely from the n-side to the p-side. As electrons are injected into the depletion region, some will radiatively recombine with holes from the p-region and emit a photon of energy $hc/\lambda = Eg = eV_d$, which forms the observed light.

The wavelength of each of the four LEDs can be measured with the Ocean Optics Spectrometer. To measure the diffusion potential, the potential at which the LED turns on, first set up the equipment as shown in Figure 2. Three of the four diodes have a maximum current of $I_{max} = 50$ mA, the fourth, LED370E, has a maximum current of 30 mA. Record the corresponding V_{max} for I_{max}. Then record the voltage V_2 for $I_{max}/2$. Take a linear extrapolation to find V corresponding to $I = 0$, that is $V = 2\ V_2 - V_{max}$.

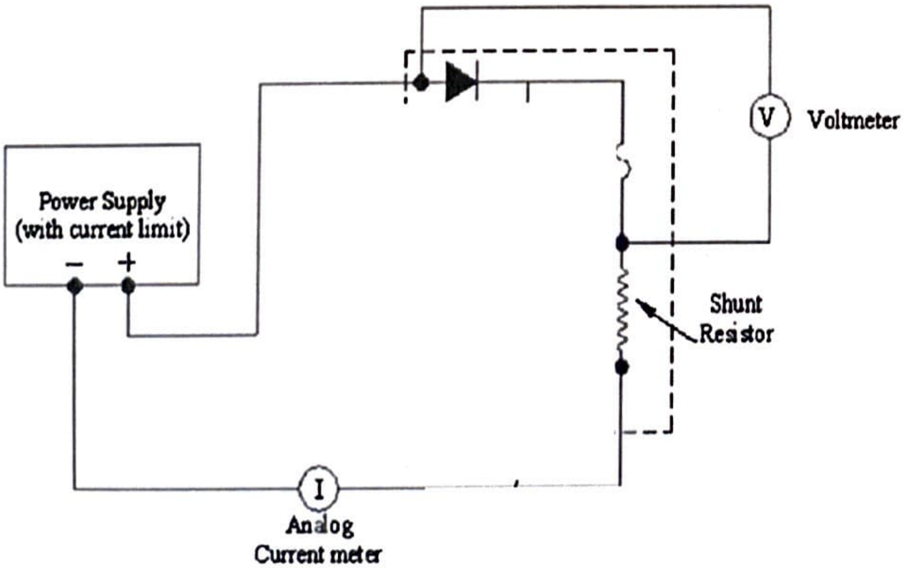

Figure 2. The circuit to the left, with a shunt resistor of 220 ohms, can be used to measure the current through and the voltage drop across the LED shown as the black arrow with a line. The positive sided of the LED has the longer "leg".