The Franck-Hertz Experiment

Purpose:

1. To verify that the spectrum of helium is discrete; i.e., that the energy levels of the electrons are quantized.
2. To estimate the transition energies of helium.

Equipment:

- Lab-Volt Power Supplies (2)
- DMM (3)
- DM 40?
- 1.5 V D-Cell Battery with Holder
- Critical Potentials Tube, Universal Stand
- Decade Resistance Box
- Patch Cords
- Tape

Theory:

The orientation of the apparatus we will use is different from that described in the text. Here the low-velocity electrons are themselves detected by a collector ring surrounding the helium (rather than their absence, as in most textbooks. The ring is kept at a potential a few volts above the cathode potential. Electrons are accelerated through a potential difference, V, and thus acquire a kinetic energy of eV.

For most energies, the electrons only make elastic collisions so they pass through the ring without contributing to the collector current. However, when an electron has the energy necessary for an electron bound in helium to make a transition to a higher level, an inelastic collision occurs. The free electron loses most of its energy, and is left with a very small velocity and is thus attracted to the ring. Therefore, the current in the ring increases.

Experiment:

1. Using one of the Lab-Volt power supplies as a DC source (use Range A), set up the following circuit to power the cathode ray tube:

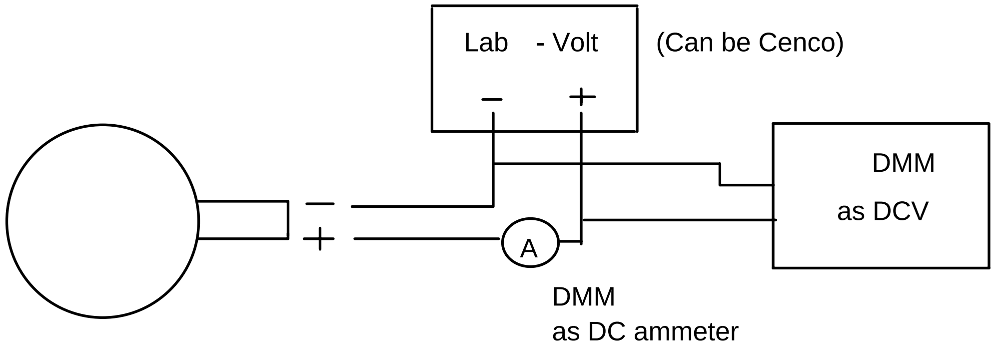

Figure 1

Set the potential to 4.0 volts and check that the current drawn is about 1.5 A. Turn the toggle switch to OFF, except when taking a measurement. This potential remains fixed throughout the experiment.

DO NOT ADJUST VOLTAGE ONCE THIS FIRST CIRCUIT IS SET-UP. ARRANGE THE REST OF THE EQUIPMENT SO THAT THE FIRST LAB-VOLT IS NOT TOUCHED--TAPE THE KNOB IN PLACE AS A REMINDER. THE TUBE WILL BLOW OUT IF THIS INSTRUCTION IS NOT STRICTLY FOLLOWED - AND IT IS EXPENSIVE.

2. Set up the following circuit (in addition to the above):

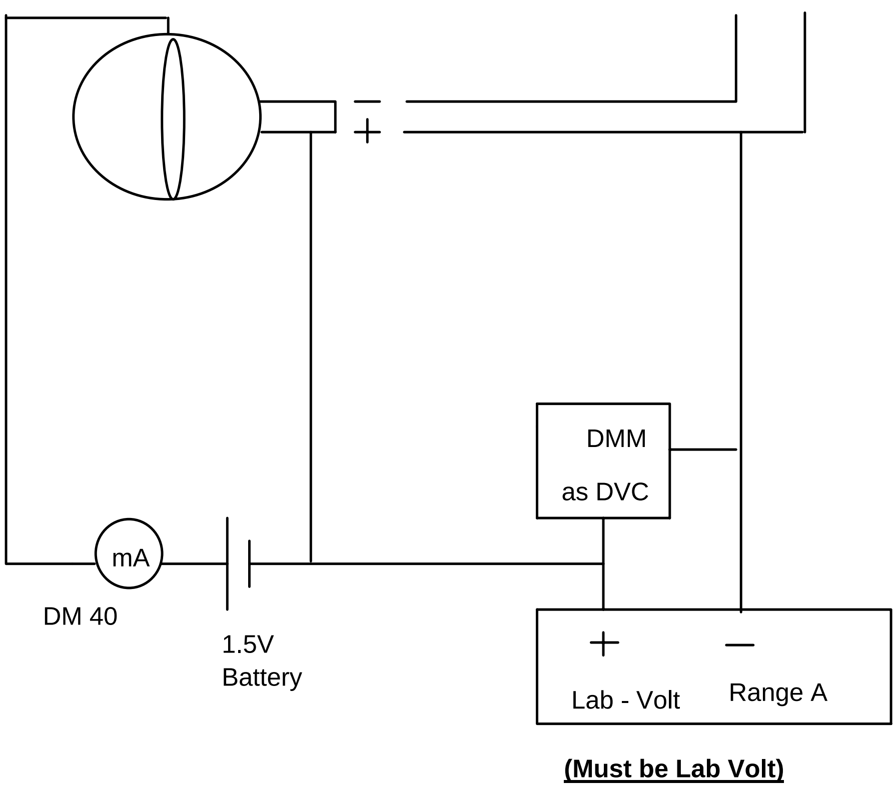

Figure 2

3. Qualitative Study: Gradually increase the cathode potential be increments of about 1.4 volts. Record both the potential and the current (mA) for each potential. Make a quick sketch of the collector current vs. the electron energy in units of *eV* (i.e., *mA vs. V*). See note below.

NOTE: It may be helpful to replace the ammeter as set up in **Figure 2** with a variable resistor (Decade Resistance Box) set at approximately 500 kΩ. You can then use the DMM as a voltmeter to read the voltage across the resister. This will give a more sensitive reading of the collector current since $I_c = \frac{V_c}{R}$. You can actually plot $V_{cathode}$ *vs.* V_C instead of I_C. Also note the DMM must be connected to the battery ground as shown.

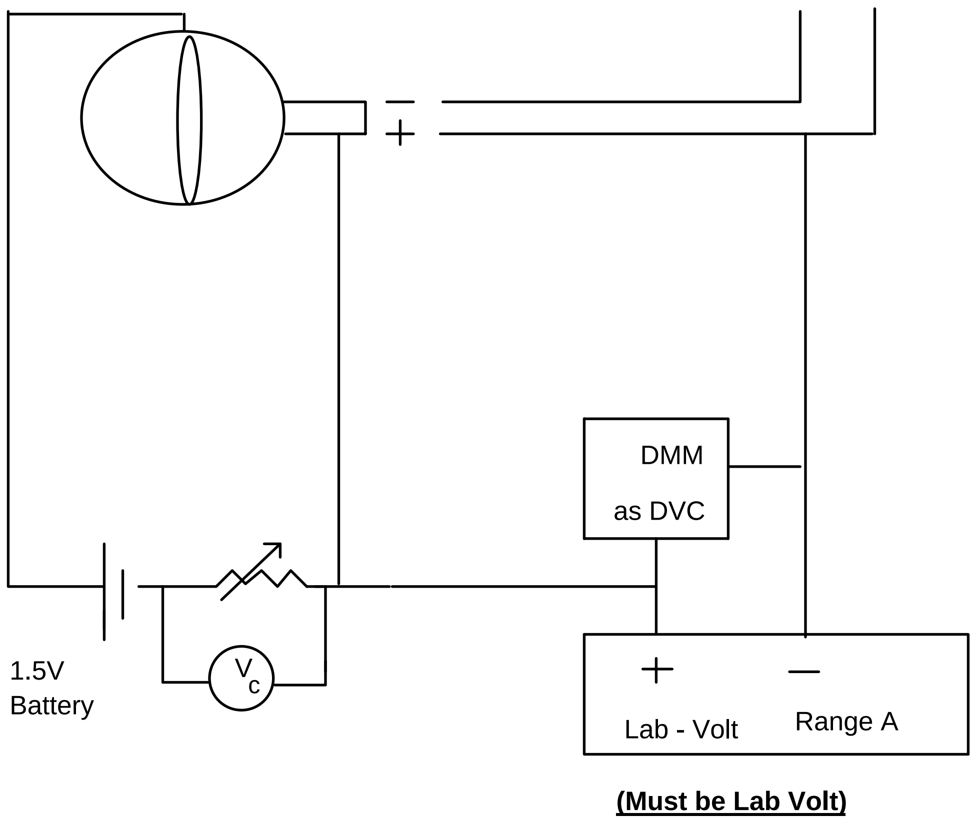

Figure 3

4. Quantitative Study: Repeat Step 3 carefully. Increase the potential by smaller increments so that you can graph a very precise curve. Take many readings to define the maxima and minima. Record your results in a (LONG) table:

$V_{cathode}$ (V)	$I_{Collector}$ (A)

Analysis:

1. Make a large graph of your results from Step 4. Choose the scale so that your graph is as large as possible.

2. Identify the transitions energies, ΔE, of helium.

3. The cathode ray gun actually emits a spread of electron velocities. This introduces a DC offset:

   $\Delta E_{actual} = E + e$ where e is the same for the various transitions.

   Compare your ΔEs to the transition energies for helium:

   ΔE_{Helium}: 19.8, 20.9, 22.9, 24.6 (ionization) eV

   What choice of e gives the best match?

Results:

Why do all the transitions studies involve transition from the ground state to an excited state?