Physics 210 Lab 2B: Franck Hertz

Andrew Rippy,* Caleb Powell, and Will Lillis
Department of Physics, Wabash College, Crawfordsville, IN 47933
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The goal of this experiment is to measure the excitation energy of mercury for transitions between the $^1S_0$ and $^3P_1$ states of mercury that result from collisions between accelerated electrons and the Hg atoms. This expected value for this transition energy $\Delta E_{Hg} = 4.9$ eV. The measured voltage separations of 5.11 ± 0.28 V for the peak fit, and 5.09 ± 0.22V for the valley both matched the expected value of 4.9 V, within a 95 % CI.

I. INTRODUCTION

The Franck-Hertz experiment was a famous experiment conducted by James Franck and Gustav Hertz in 1914 which supported the theory of Bohr that atomic energy levels were quantized. In Bohr's theory, the transitions between atomic energy levels were caused by the absorption or emission of photons which have energies equal to the difference between the final and initial energy levels. If these energy levels are real, than any mechanism which can transfer energy to the atomic electrons should cause these energy levels, including collisions. Franck and Hertz tested this by passing an electron beam in a vacuum tube containing a vapor of mercury atoms. As they slowly increased the voltage accelerating the electrons, they observed that the number of electrons reaching the cathode slowly rose and then suddenly dropped before rising again. This could be explained by the electrons undergoing inelastic collisions if the electrons had sufficient energy to boost an electron in the mercury atom to a higher energy level. By conservation of energy, the electrons would then lose an amount of kinetic energy equal to the difference in atomic energy levels.

II. THEORETICAL MODEL

When the electrons have sufficient kinetic energy,

$$K \approx \Delta E_{Hg} \tag{1}$$

they can transfer this energy to the atom, but this leads to a loss of current in the detection system. However, if we increase the accelerating voltage, the electrons can undergo multiple collisions, regaining energy from the field after the collisions. This leads to a number of distinct peaks in the current data, which we can then curve fit to find the peak/valley voltages. The voltage separation between these peaks ΔV implies that the difference in energy levels is $\Delta E_{Hg} = e\Delta V$, the ΔV can be found by plotting a linear fit of the peak and valley voltage values.

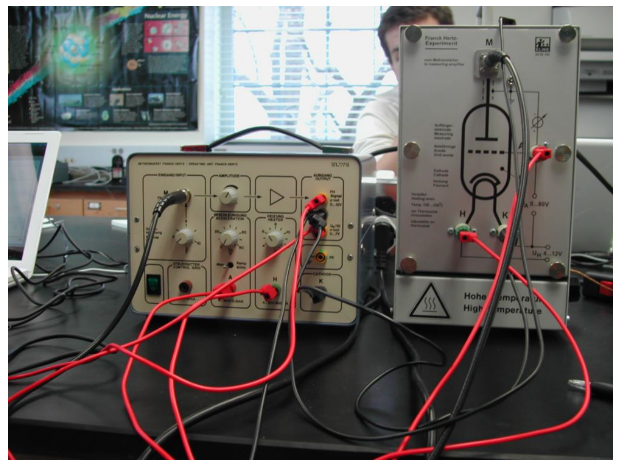


FIG. 1. A photo of the power supply and oven setup

A. Procedure

1. After connecting the sensors to the logger pro software, and setting up the oven-mercury apparatus, set up the Vernier voltage sensors to "Raw Voltage $\pm 10V$", set the collection time to 120 seconds, and set up the graph plot to have accelerating voltage is plotted along the x-axis and the current is plotted along the y-axis.

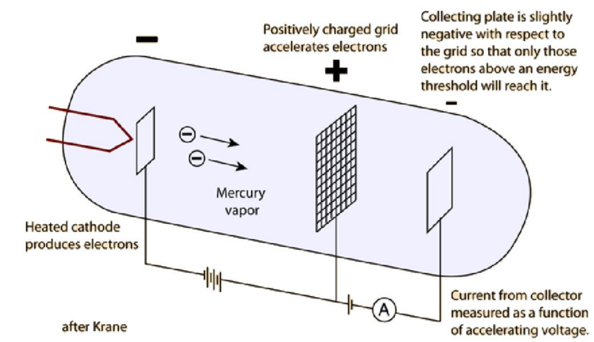
2. Turn the oven on, and heat it to about 200 °C.

3. Make sure all knobs are turned to zero and ramp switch is set to manual.

4. Turn Heater to 8 V, from manual.

5. Turn Amplitude to middle position.

6. Start data collection, and slowly turn the accelerating voltage from 0 to 80 V, watching the peaks form. Make sure to move the knob slowly for higher quality data, while trying to get as many peaks as possible.



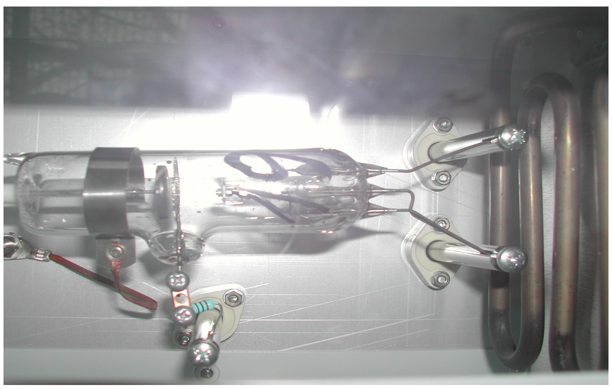


FIG. 2. A picture of the inner apparatus

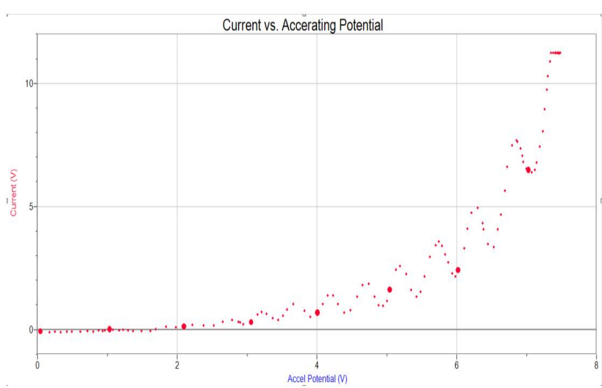


FIG. 3. A picture of the measured voltages

B. Data

III. ANALYSIS

For each valley and peak of the collected voltage data, a quadratic fit of the form:

$$y = A(x - B)^2 + C$$

was used to determine the peak and valley voltages. y is the measured current, and x is the measured accelerating potential V. The 'B' value is the value for the peak-valley voltages, as it represents the value for the peak or valley of the quadratic fit. The errors were calculated from the

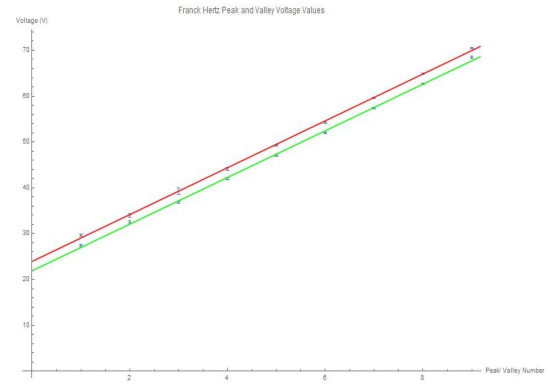


FIG. 4. A linear fit of the peak and valley voltages

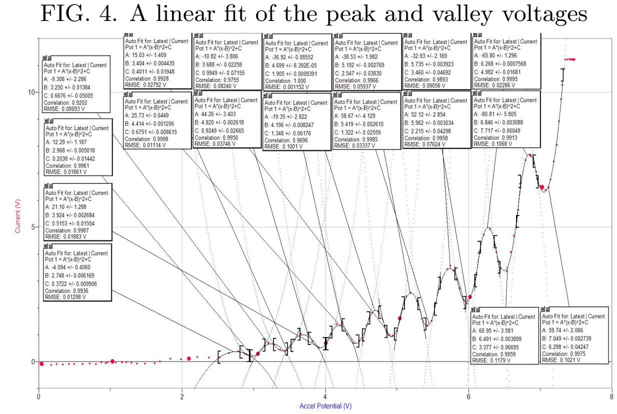


FIG. 5. A quadratic fit for each voltage valley/peak

instrument uncertainty as well as fit uncertainty. The peak and valley values were then graphed, and a linear fit was applied to find the slope, which was the voltage separation between the peaks. We found the voltage peak to peak separation to be $5.11 \pm 0.28V$ and the valley - valley separation to be $5.09 \pm 0.22V$. Potential improvements for these measurements could be increasing data collection rates, running multiple trials, or utilizing higher detailed instruments, to provide improved voltage and current readings.

IV. CONCLUSION

The measured voltage separations of 5.11 ± 0.28 V for the peak fit, and 5.09 ± 0.22 V for the valley both matched the expected value of 4.9 V, within a 95 % CI. This is consistent with quantization of energy, and matches our model.

ACKNOWLEDGEMENTS

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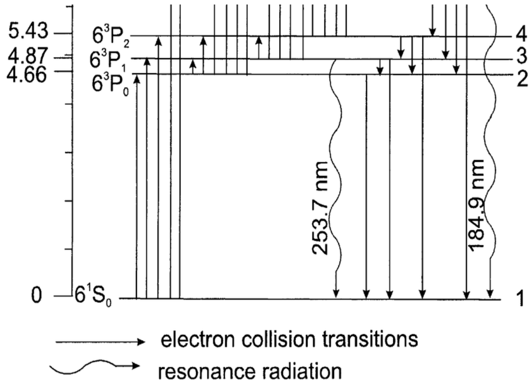

FIG. 6. An energy level diagram of mercury

* anrippy22@wabash.edu