Frank-Hertz Experiment

Jason Morgan
Department of Physics, Old Dominion University, Norfolk VA 23529
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The purpose of this experiment is to demonstrate the quantized energy levels in electrons. To achieve this, electrons (emitted from a heated lament) are accelerated through a neon gas by an electric field and the resulting current was measured using an oscilloscope.

1. INTRODUCTION

Niels Bohr introduced the concept of discrete energy levels within an atom when he proposed the Bohr model in 1913. At the time this fundamental concept was entirely theoretical, however, within a year James Franck and Gustav Ludwig Hertz presented their findings on the Franck-Hertz experiment. In this experiment, mercury was trapped in a glass tube along with an anode, cathode, and control grid. The tube was heated to produce mercury gas and the cathode was heated to emit electrons. A potential difference was applied to the tube to accelerate the electrons towards the control grid which, once passed, allowed them to reach the anode and be measured as current. As these electrons transversed the tube, they collided with mercury atoms and were either deflected elastically (without losing kinetic energy) or inelastically (losing kinetic energy). As the accelerating potential was raised, the resultant current rose proportionally, indicating a preservation of kinetic energy and elastic collisions. However, once the accelerating potential reached a critical value, the current dropped drastically, indicating a sudden switch to inelastic collisions. Raising the potential further repeated this cycle at regular intervals of 4.9 V. This astounding result indicated that the exchange of kinetic energy between the electrons and atoms happened only at quantized energy levels of 4.9 V. A result that agreed with and confirmed the Bohr model as well as current theories regarding atomic energies.

2. EXPERIMENTAL SETUP AND PROCEDURES

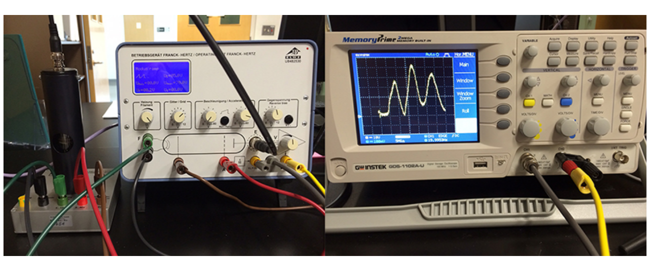

FIG. 1: Experiment set-up - Franck-Hertz tube filled with neon

Neon gas is used in place of mercury due to its advantage of being gaseous at room temperature as well as not being posionus. This elimnates the need to head the tube in and oven to vaporize mercury. The apparatus used consists of a neon filled tubeand a power supply. The power supply controlls the voltages to the emitting filament (cathode), collection anode, accelerating potential, and control grid. It also included connection points for an oscilloscope and a digital readout of the voltages selected (see Fig. 1).

To begin the procedure connections were made between the tube, power supply and oscilloscope. Each device was turned on and the voltage to the cathode (heated filament) was gradually increased until a light glow was visible which was at 8.2 V. The control grid was held at 8 V and the collection anode held at 5 V. The accelerating potential was set to start at 0 V, then increase to a maximum of 70 V before dropping back down to 0 V and repeating the cycle. As it did, these voltages were sent, along with the anode voltage, to an oscilloscope. The oscilloscope was set to X-Y mode, i.e., the voltages were graphed using the varying accelerating voltage as the x value of each point, and the collecting anode voltage as the y value (see Fig. 2).

This graph displayed three distinct transitional points, visible as sharp dips in the curve. Using the built-in capabilities of the oscilloscope, the x values of these transition points were found and the difference between them

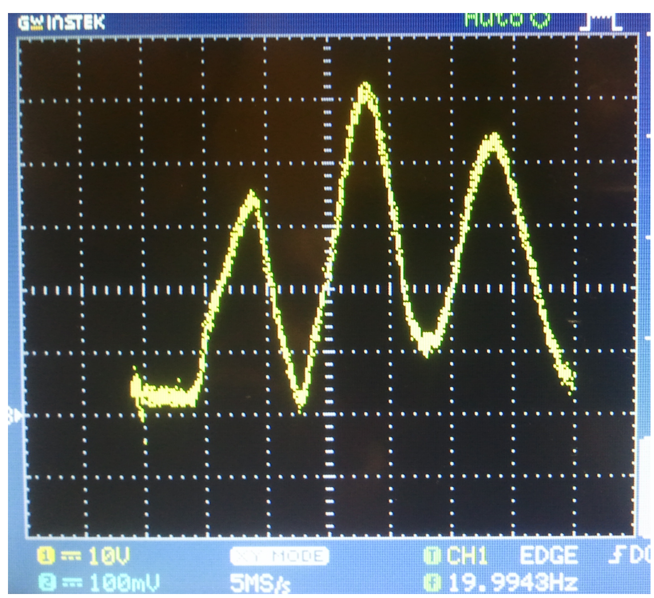

FIG. 2: Oscilloscope giving readings in X-Y mode

measured (see Table. I). After saving this data, the maximum and minimum voltages of the accelerating potential cycle were altered while observing the X-Y curve, and notes were taken as to their effects. Finally, returning the accelerating voltages back to initial levels, the voltage supplied to the emitting cathode was adjusted and observed.

TABLE I: Voltage Separation Between Peaks

Peak No	Voltage Difference (V)
1	17 ± 1
2	20 ± 1
3	24 ± 1

3. RESULTS AND DISCUSSION

It was found that regardless of any alterations to the various voltages, the distance between peaks in the curve (voltage difference at which collisions become inelastic) remained steady. It was observed that altering the cycle of accelerating voltage simply limited or expanded the portion of the curve that was displayed without altering the shape of the curve itself. Lowering the voltage of the emitting cathode reduced the amplitude of the wave and increased the noise (to the point of unrecognizability) however, it also did not alter the peak distance. In all cases the average distance between peaks of the wave was 20 ± 1 V which agrees very well with the expected value of 19 V [1] having a percent difference on only 5%.

Once absorbed, the energy gained by the neon atoms must be re-emitted. The wavelength of this emission can be found using the following equation:

$$\lambda = \frac{hc}{E}, \tag{1}$$

where λ is the wavelength in meters, h is Planck's constant (4.13×10^{-15}) in eV-s, c is the speed of light (2.99×10^{8}) in m/s and E is the measured energy of 20 V per electron. Using this equation, the wavelength of emission is predicted to be 6.2×10^{-8} m, or 62 nm.

4. CONCLUSION

This experiment was successful in reproducing the results of the original Franck-Hertz experiment. It is apparent that the same phenomenon are being measured and add still more support to its historic discovery.

[1] Wikipedia. "Franck-Hertz Experiment.", *Wikipedia*, Wikimedia Foundation, 03 Sept. 2014. Web. 27 Mar. 2014.

[2] M. Nikoli, C. I. Sukenik, *Frank Hertz Experiment with Neon*, (Old Dominion University, Physics 413, 2014).

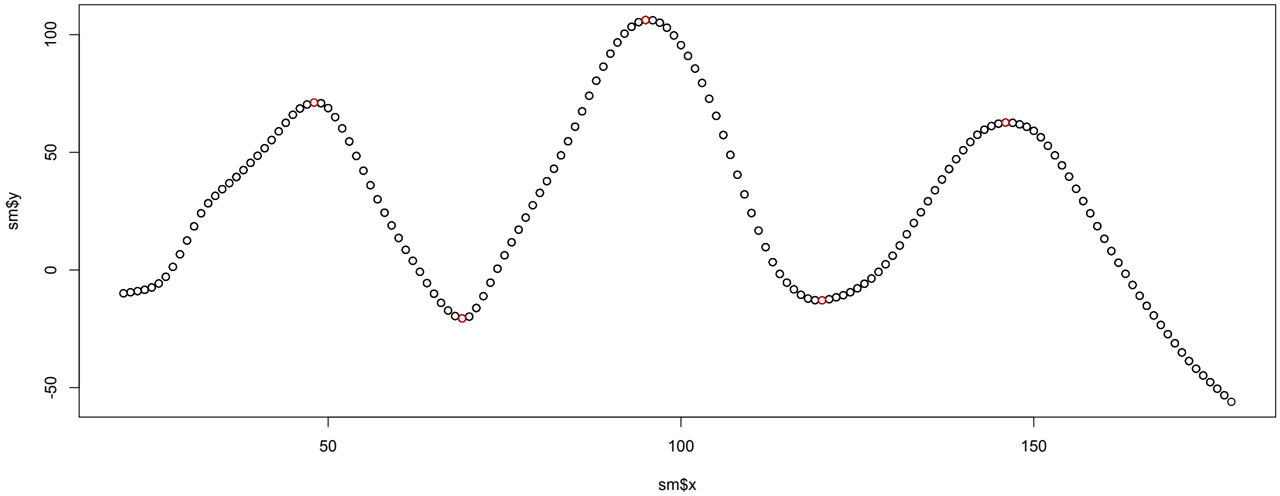

FIG. 3: Saved Data from X-Y Graph, Smooths, the area of the circles represents the error.