Franck Hertz

Sreela Das

Wednesday 8$^{\text{th}}$ April, 2015

Class: Intermediate Experimental Physics II
Week: 6
Date Performed: March 24, 2015
Partners: Alvin Modin, Lauren Hirai

Objective

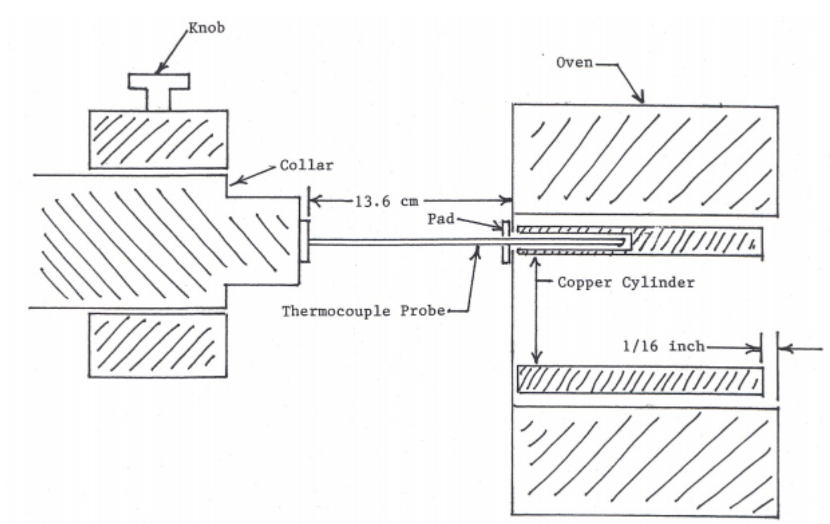
The purpose of this experiment was to familiarize oneself with the Franck Hertz Apparatus and to demonstrate the existence of excited states in a mercury atom. This observation agrees with quantum theory (which says electrons occupy only discrete, quantized energy states and therefore the current observed would fall sharply just above these voltages)

Theory

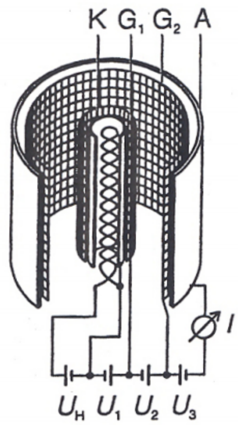
Electrons exist in atoms at quantized energy-levels, in specific states. This experiment verifies this quantized model of the atom by showing that there are specific energies that will excite the atoms. The gas-filled tube is heated until the pressure is significantly low. At this pressure, the potential difference between the cathode and the anode is enough to emit electrons from the cathode and cause a flow of current between the cathode and anode. These emitted electrons pass through a mercury tube with an accelerating voltage. If the thermion has sufficient energy (which is proportional to the accelerating voltage), an inelastic collision with a Mercury atom releases an electron from the Mercury atom by losing energy equal to the energy required to release a single electron from the Mercury atom.
After the initial dip, as the control grid sweeps the range of voltages, the accelerating voltage resumes its quasi-linear trajectory until it gains enough energy to release yet another electron.
The plot demonstartes that there is a difference of $\approx 4.9V$ between successive peaks in accelerating voltage.

Setup

Our setup consisted of an oscilloscope, an interface to the computer and the Franck-Hertz tube apparatus.
The Franck-Hertz tube itself consists of a cylindrical mercury tube and a cathode, both of which are heated to about 186 °C.



Oven and Thermocouple

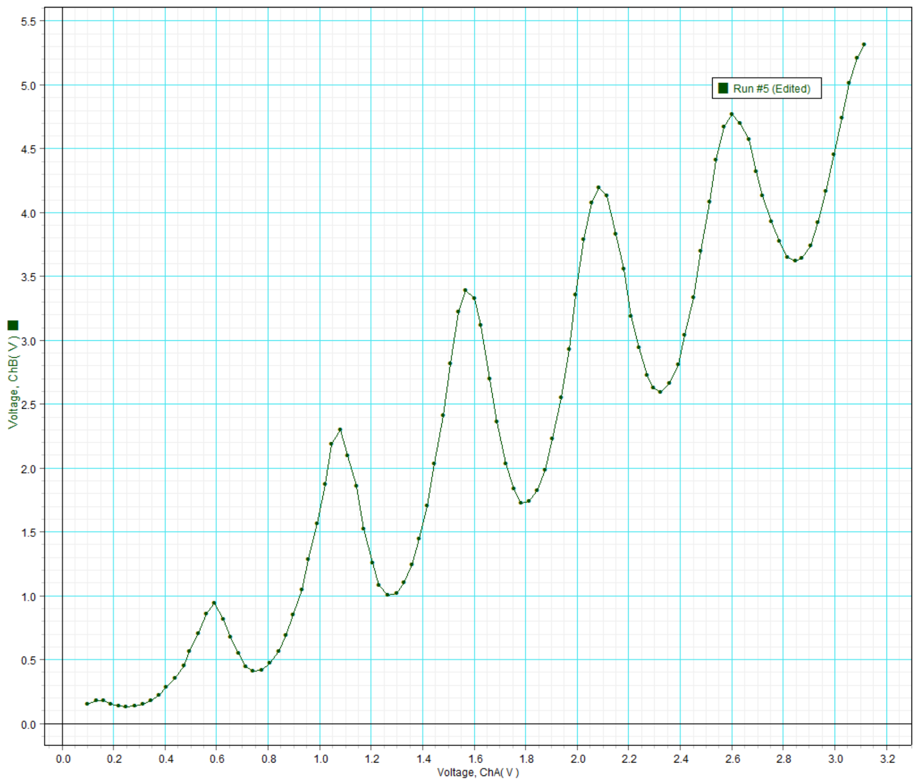


Schematic of the Franck-Hertz Tube showing the tube (in the middle), the grids across which the potential is measured, and marking the voltages and currents to denote what each symbol refers to in the experiment

Procedure

1. The Franck-Hertz tube was ensured to be inserted into the copper tubing in the oven to ensure even heating on all sides.
2. The power for all devices was turned off and all the variable knobs were also set to zero.
3. Once the tube was heated to the set-point temperature, the system was powered on.
4. The values of the Voltage on the two grids is varied – U_1 (Potential of the control grid) increased and U_3 (Retarding voltage) decreased – until the Voltage peaks are visible and emphasized.
5. The voltage display on DataStudio was set to display the potential difference between the grid and the cathode.
6. The input pulse was set to a single ramp Voltage and the current is plotted against the potential difference beteen the grid and the cathode for a sweep of 0V to 30V
7. The voltages at the peaks were recorded for further analysis

Data and Analysis



The above plot shows the Accelerating Voltage (Voltage B or U_2) plotted against the Current (corresponding to Voltage A). The coordinates at the peaks are listed below.

Voltage A (in Volts)	U_2**(in 1.0 Volts)**
0.942	0.591
2.300	1.079
3.889	1.567
4.194	2.085
4.711	2.603
5.318	3.115

The voltage differences between consecutive peaks was calculated and can be seen in the table below:

Peaks	**Voltage Difference(in V)**
1-2	4.88
2-3	4.88
3-4	5.18
4-5	5.18
5-6	5.12

The Average value for the difference between peaks was: 5.048 ± 0.15V which places the accepted value of 4.9V within our range of uncertainty.

Questions

Why is it better to have the cathode indirectly heated rather than directly heated?
Heating the cathode indirectly allows a slower heating process which ensures that the cathode is heated more evenly. Direct heating also poses a risk of heat damage due to overheating.
When the oven temperature is too low, why is there the possibility of a discharge?
Lower temperature corresponds to lower pressure which could allow air to breakdown under lower voltage than required for electron discharge.
Why should the oven temperature not be too high?
Over-heating of the apparatus could damage the cathode tube or allow ionization of the mercury which would result in unexpected behavior yielding incorrect results
Does the first peak occur at $(U_1 + U_2) = 4.9$ V? Can you think of reasons as to why it would not?
No, the first peak did not occur at $(U_1 + U_2) = 4.9$ V. This was likely because it takes energy for the thermion to reach the Mercury tube and therefore there is a minimum additional energy required for the release of an electron from the Mercury tube.

Conclusions

The distance between successive peaks was 5.048 ± 0.15 V which was 4.9 V, as expected since 4.9 V is the energy required to emit an electron from a Mercury atom. The first Voltage peak was at $(U_1 + U_2) = 6.8$ V not at $(U_1 + U_2) = 4.9$ V, which was likely due to the fact that it takes energy for the thermion to reach the Mercury tube and therefore there is a minimum additional energy required for the release of an electron from the Mercury tube.