Experiment No. 2

FRANK HERTZ EXPERIMENT

I. OBJECTIVE

Determine the excitation potential of an argon atom using the Frank-Hertz tube.

II. APPARATUS

Frank-Hertz tube, continuously variable power supply (0-95 V), cathode ray oscilloscope, digital voltmeter, digital ammeter.

III. THEORY

In 1913, Niels Bohr proposed that electrons in atoms can exist only in discrete bound quantized energy states. In 1914, James Frank and Gustav Hertz performed an experiment which demonstrated the existence of excited states in mercury atoms confirming Bohr's idea.

Their classic experiment involved a tube containing a low pressure mercury gas fitted with three electrodes: one electron emitting cathode, a mesh grid for acceleration and an anode. The anode was held at a slightly negative electrical potential relative to the grid (although positive compared to the cathode so that the electrons had to have small amount of kinetic energy to reach it after passing through the grid). The experiment uses inelastic scattering of electrons by gas atoms.

As the accelerating voltage increases, more and more electrons arrive at the anode and the current rises. Since an atom is much heavier as compared to an electron, the collisions of electrons with gas atoms are almost elastic in nature and the electrons merely bounce off in a direction different from its original one. When the accelerating voltage equals the excitation potential of the gas atom, the energy of electrons is given completely to the gas atoms and there is a sudden drop in the current. This drop is attributed to inelastic collisions between the accelerated electrons and the atomic electrons. The sudden onset suggests that the gas electrons cannot accept energy until it reaches the threshold for elevating them to an excited state.

IV. EXPERIMENTAL SETUP AND APPARATUS DETAILS

The schematic diagram is shown in Figure-1. The grid G_1 helps in minimizing space charge effects. The anode is maintained at a potential slightly negative with respect to the grid G_2 which helps in making the dips in the current more prominent. In this experiment, the current is measured as a function of V_{G2K}.

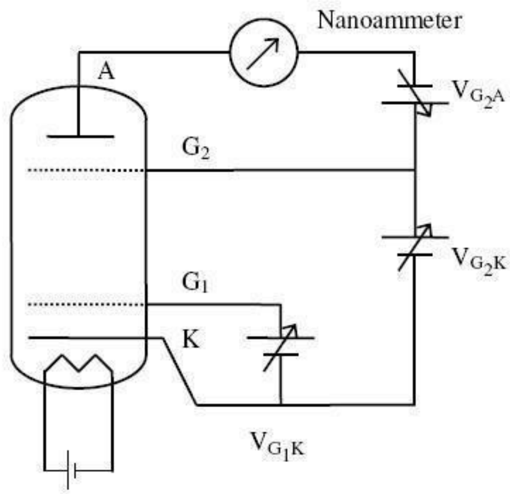

Figure 1: Schematic of Frank Hertz Experiment

As shown in Figure-2, the actual setup is made up of argon filled tetrode which is attached to socket located at the rear of the setup. The front panel shows knobs for continuously variable power supplies for filament, V_{G1K} (1.3-5 V), V_{G2A} (1.3-12 V), V_{G2K} (0-95 V) respectively and panels for multi-range digital voltmeter and multi-range digital ammeter. In addition, there is a voltage display selector switch and a manual/auto switch in the center of the front panel. The output current can be read on the current meter in manual mode and can be read on a cathode ray oscilloscope using auto mode.

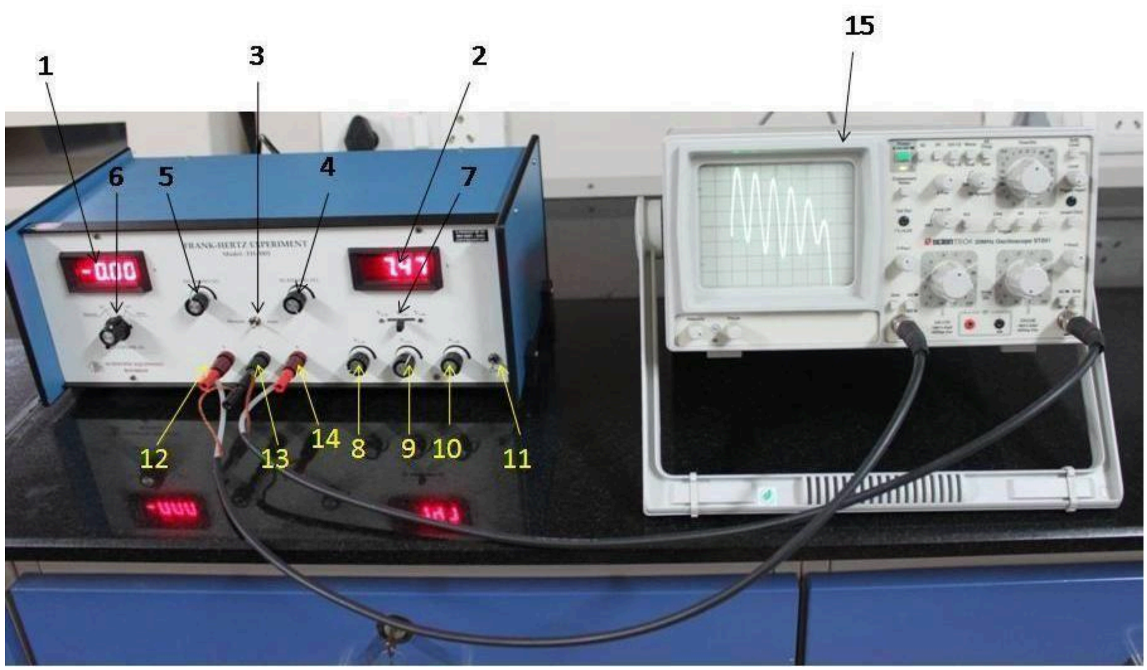

Figure 2: Frank Hertz Apparatus

1.	Ammeter	9.	V_{G2A} adjust knob
2.	Voltmeter	10.	V_{G2K} adjust knob
3.	Manual-Auto switch	11.	Power switch
4.	Scanning voltage knob	12.	Y-output terminal
5.	Filament voltage knob	13.	Ground terminal
6.	Current multiplier knob	14.	X-output terminal
7.	Voltage display selector	15.	Cathode ray oscilloscope
8.	V_{G1K} adjust knob		

V. PROCEDURE

(1) Before the power is switched ON, make sure that the control knobs are at their minimum position and current multiplier knob at 10^{-7} position. Then switch ON the power.

(2) Turn the Manual-Auto switch to manual and adjust the voltage parameters to the following values:

Filament voltage = mid position, V_{G1K} = 1.5 V, V_{G2A} = 7.5 V, V_{G2K} = 0 V, Current multiplier: 10^{-9} A.

(3) Rotate V_{G2K} knob and observe the variation of the current with increase in V_{G2K}. The current would show maxima and minima periodically. Take systematic readings of V_{G2K} versus current at an interval of 1 V. Plot a graph with output current on Y-axis and accelerating voltage V_{G2K} on X-axis. Find the voltage difference between two consecutive peaks or valley points and tabulate them against the multiplicity order.

Note: Note the immediate value of $V_{G2K.}$

(4) Again slowly minimize the V_{G2K} voltage to minimum and subsequently, V_{G1K}, V_{G2A} and filament voltage knobs to minimum position. Turn the Manual-Auto switch to Auto and connect the Y, G and X sockets to Y, G and X terminals of oscilloscope. Put the scanning range switch of the oscilloscope to X-Y mode. Switch on the oscilloscope and adjust the Y and X shift to make the scan base line on the bottom of screen. Adjust the voltage parameters to the values mentioned in step (2). Rotate the scanning knob of the

instrument and observe the waveform on the oscilloscope screen. Adjust the Y-gain and X-gain of the oscilloscope to make the waveform clear and Y-amplitude moderate. Rotate the scanning potentiometer clockwise to end. Wait for 2-4 minutes till the waveform develops completely. Note down the scale on the x-axis knob of CRO in your journal sheet. Stick a trace paper on the CRO and trace the waveform on it. Stick the trace paper on the journal sheet and mark the voltage differences between two consecutive peaks/valley points for all the pairs and mention them in the traced waveform. Again slowly minimize the V_{G2K} voltage to minimum and subsequently y, V_{G1K}, V_{G2A} and filament voltage knobs to minimum position. Switch OFF the apparatus and the CRO.

VI. RESULTS AND CALCULATIONS

Calculate the average value of the excitation potential of an argon atom using manual as well as auto modes. Calculate the standard deviation using five data points collected in manual as well as auto mode and mention it in the result

VII. PRECAUTIONS

(1) Before taking the systematic readings, gradually increase the value of V_{G2K} to a maximum. Adjust the filament voltage if required such that max. reading is about 1000 in the X 10^{-8} range. This will ensure that all the readings could be taken in the same range.

(2) During the experiment (manual), when the voltage is over 60V, please pay attention to the output current indicator. If the ammeter reading increases suddenly, decrease the voltage at once to avoid the damage of the tube.

(3) Whenever the Filament Voltage is changed, please allow 2/3 minutes for its stabilization.

(4) When the Franck-Hertz Tube is already in the socket, please make sure the following before the power is switched 'ON' or 'OFF', to avoid damage to the tube.

(a) Manual - Auto switch is on Manual and Scanning and Filament Voltage knob at its minimum position (rotate it anticlockwise) and Current Multiplier knob at 10^{-7}.

(b) V_{G1K}, V_{G2A}, and V_{G2K} all the three knobs are at their minimum position.

VIII. LEARNING OUTCOMES

1. How to find excitation potential for an atom.
2. One can think of making a Frank Hertz tube filled with a different gas and find excitation potential for the atoms of the gas.

IX. REFERENCES

1. J. Franck and G. Hertz, Verhand. Deut. Physik Ges., 16 (1914) 457.

2. Arthur Beiser: Perspectives of modern physics.