Physics Department XQE-410
Brown University

The Frank-Hertz Experiment

Purpose: The experiment verifies that energy is arranged into discrete packets or quanta. The Frank-Hertz tube accomplishes this verification

Apparatus: Frank-Hertz tube, electric oven, Neva Frank Hertz operating unit, digital thermometer, two digital multimeters, digital oscilloscope.

References: Richards, Sears, Wehr, Zemansky, *"Modern University Physics"*, Addison-wesly Press, pp. 747-748.
Melissinos,A., "*Experiments in Modern Physics"*, Academic Press 1st ed., pp. 8-17.

Description of the tube:

1. The tube has a planoparallel system of electrodes in order to avoid deformation of the electric field. The distance between the anode and the collector is small in comparison to the average free path of electrons whereas the distance between the cathode and perforated anode is large in comparison to the free path of electrons to assure the highest probability of collisions

2. A platinum ribbon with small Barium-oxide spot serves as a direct heated cathode. A diaphragm connected with the cathode limits the current and eliminates the secondary reflected electrons making the electric field more inform.

The temperature in the oven kept constant by a thermostat, which can be regulated from the outside. A hole in the top of the cabinet is provided for thermometer.

Procedure:

Connect Frank-Hertz tube and the Neva electronic operating unit as shown in diagram in Neva reference manual (it will usually be pre-wired for you). Switch on the heater and wait for the oven to heat up. It takes about 20 minutes to reach the proper temperature, a digital thermometer will read out the temperature. The temperature of the cabinet should be adjusted to 180° C ± 5 **(Caution: extremely hot!).**

Once the desired temperature is stabilized power on the Neva electronic operating unit. The filament heating control knob has been preset to about 6.3 AC volts and should not be adjusted (too high a voltage can burn out the filament).

Set the manual/ramp toggle switch to manual mode.

Set the accelerating voltage knob U_b to zero volts.

Set the retarding voltage U_G to about 1.5 Volts DC

Adjust the gain control of the operating unit to its maximum sensitivity (turn the knob as far right as it will go).

Increase very slowly the accelerating voltage, read the current and voltage and record it as shown in the Figure 3 diagram of the Klinger Frank-Hertz Tube manual. Note that the Neva electronic operating unit outputs the accelerating voltage decreased by a factor of 10, and converts the measured current to a voltage. The conversion factor is 1V= 0.7 microamps for the gain set to minimum sensitivity and 1V=7 nanoamps for the gain set in maximum sensitivity setting.

To clearly define the maximas, which occur at lower voltage, it may be necessary to set the gain control knob to maximum sensitivity.

If you have time record I-V curves at different temperatures and/or different retarding potentials. You can also output the curves to an oscilloscope for display using the ramp function of the Neva electronic operating unit. Set the oscilloscope in the XY display mode and see if you can adjust the scope and electronic operating unit controls so as to get a display similar to figure 4 in the Neva manual. The system should be wired according to figure 3. If you have trouble ask your TA for assistance.

<u>Note:</u>

1. Starting the operation without pre-heating could cause a short circuit in the tube die to excess mercury between the electrodes.

2. If the tube is overheated, the emission current is small and maxima and minima are unrecognizable. For checking purposes remove the tube from the oven for about half a minute. Then if the tube was overheated, maxima and minima can be found. In this case operate the tube at lower voltage.

3. When the tube is not sufficiently heated, the reverse happens and again maxima ad minima are undistinguishable. When this happens the value must be operated at higher temperature.

4. Depending on the temperature of the tube one must be careful to watch for collisional ionization in the gas which may occur at a high enough acceleration voltage. You will see a bright purple glow in the tube when this happens, your data will fine if you stay below this voltage.

Questions:

1. Why is the first maximum at 7 V and not at 4.9 V? (Hint: contact potential)

2. What is the wavelength if the spectral line emitted by the mercury vapor? What are excitation potentials?

3. Why is the temperature adjusted to the specified value given in the experiment outside of the fact that tube can only withstand a certain maximum temperature?