

Physics 307 Laboratory

Experiment 2: Franck-Hertz Experiment

Motivation:

Bohr's theory of the atom was in part based on the fact that the emission spectrum of atoms is discrete. It was also known that atomic vapors absorbed radiation only for discrete wave lengths. In 1914, Franck and Hertz observed that the transfer of energy to atoms by inelastic electron scattering exhibits a discrete spectrum provide that the atom is not ionized.

References:

Experiments in Modern Physics, by Melissinos pp. 8-18

Foundations of Modern Physics, Tipler pp. 175-177, pp. 162-170

Procedure

Using the circuit diagram on the next page as a guide connect wires from the Franck-Hertz apparatus to the Franck-Hertz oven/tube assembly and the chart recorder or Pasco interface box.

Tips and Precautions:

1. Before plugging in the oven, insert the thermometer into the hole at the top of the oven. The "immersion line" should be about 1 cm inside the oven.
2. Set the thermostat control on the side of the oven at "4" before plugging in the oven. You will have to raise it after the heater cycles off but, if you start it higher, the temperature may overshoot to an unsafe level. The first time the heater shuts off, you can start increasing the thermostat setting while watching the thermometer closely. Adjust until the temperature is centered at about 180°C (it will probably cycle plus and minus 5° or so around this temperature.) The required thermostat setting is approximately $6\frac{1}{2}$.
3. NEVER ALLOW THE TEMPERATURE TO EXCEED 195 °C.
4. The actual accelerating voltage (between the cathode and the screen electrode) appears at the "Monitor" terminals. You can measure this voltage with a digital voltmeter (with both sides floating from ground) to calibrate the X-axis on the recorder. The voltage at the recorder output comes from a differential amplifier so that it can be referenced to ground. It is about $\frac{5}{70}$ of the actual accelerating potential.

In your lab book you should:

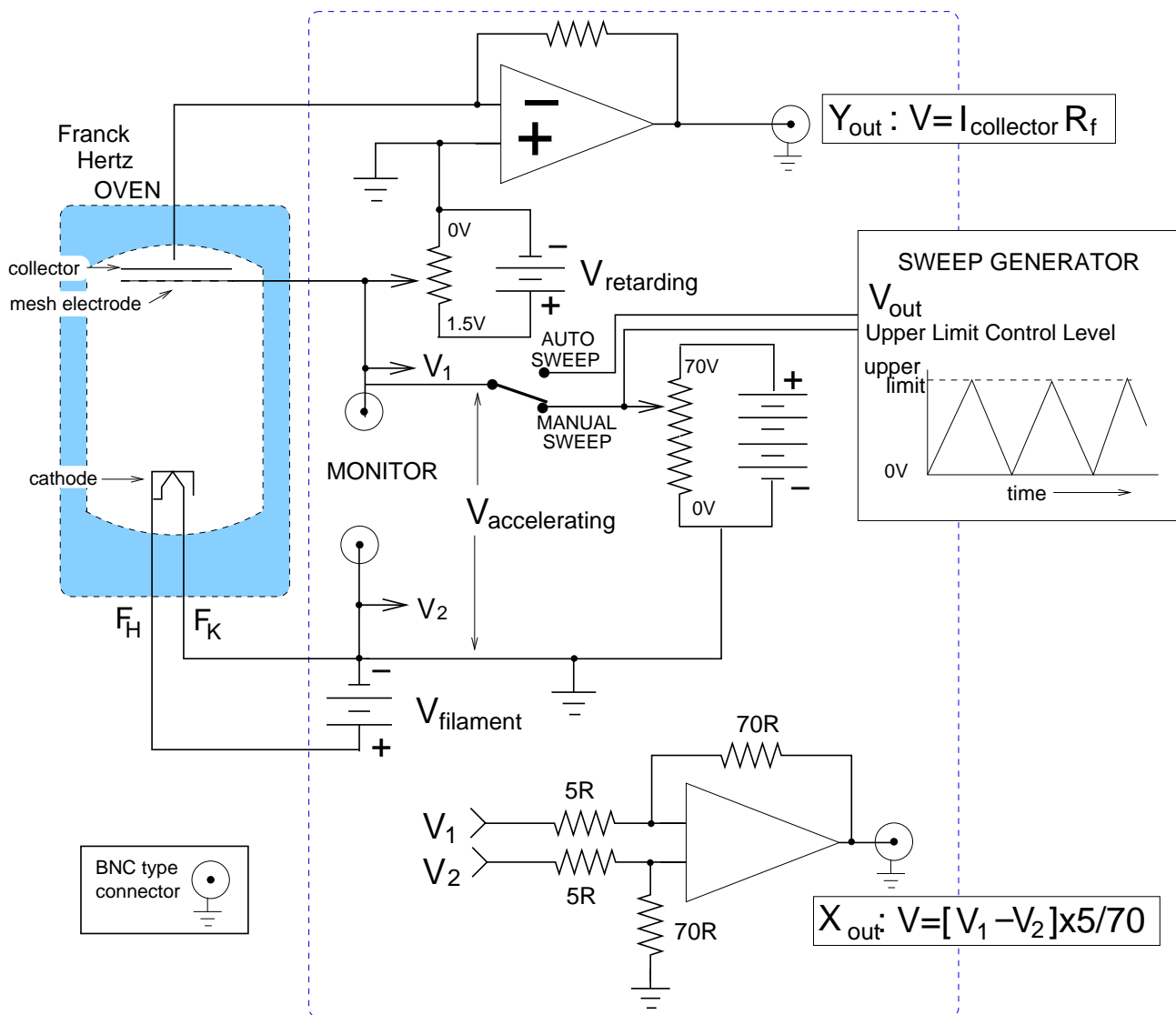
1. Provide a sketch of the Franck-Hertz tube and a circuit diagram for this experiment. The diagram in this handout may be included in your data book.
2. Obtain several sets of data (graphs) using the X-Y plotter or Pasco software. For each set, plot a calibration curve on the same graph. Independently, compute a mean of the voltage difference between the peaks (excitation curve). The instructor will discuss one or two methods of obtaining the peak positions.

3. Once you obtain curve using the built in ammeter you should then perform the same measurement using the Keithley 610 electrometers which provide much better sensitivity. The output plugs are located on the back of the instrument.
4. For some intermediate value of the acceleration voltage, plot the potential distribution in the Franck-Hertz tube. For this same value of the acceleration voltage, plot the kinetic energy of an electron which makes No (zero), one, two, etc. collisions. (Note: the graphs in Melissinos are incorrect for your tube.)

Questions (to be answered in your notebook)

1. What wavelength of light would be emitted in the electronic transition which de-excites the Hg atom?
2. Why is the spacing to the first peak different than the spacing between successive peaks?
3. Why is the oven necessary?

Franck-Hertz Controller



Using the PASCO 750 Interface

Although the X-Y plotters are, in many ways, simpler than using the PASCO interface for data acquisition this device streamlines the data recording process and allows subsequent data processing (through spreadsheet software) and analysis (through curve fitting software). There should be three icons on your desktop, (1) Science Workshop, (2) Microsoft Excel, (3) CurveExpert, which allow you to work up your data.

The PASCO Science Workshop (SWS) program works primarily through its GUI (graphical user interface) and its drag and drop features. In this experiment you will need to record (1) the accelerating voltage and (2) the counter-electron current *vs.* time using two of the three available inputs. After double clicking on the SWS icon you should:

1. Drag and Drop twice from the Analog Plug Sensor onto the A, B and/or C Analog Channel icons. You will be given a choice of inputs; choose the Voltage Sensor.
2. Drag and Drop twice from the Graph icon onto the two respective Analog Channel icons. With two graphs you can plot either voltage *vs.* time or voltage *vs.* tube current (remembering, of course, the output to the Pasco interface is actually a voltage signal).
3. Drag and Drop twice from the Table icon onto the two respective Analog Channel icons. You can increase the number of columns by clicking on the proper icon.
4. Click on the MON icon to begin data acquisition without creating a permanent data set.
5. Click on the REC icon to begin data acquisition with creation of a permanent data set.
6. To remove an icon or data set click once on said item and then click the Delete key.
7. NOTE: You should also adjust the sampling rate by clicking on the Sampling Options icon. Sampling rates in excess of 20/sec often give unacceptable results.
8. To move a data set to Excel it is easiest to use the mouse to highlight a region of interest and then Copy (CTRL+C) into the cut and paste buffer. Once copied you can use the Paste feature to import it into Excel.

Excel has relatively limited curve fitting capabilities but is relatively easy to use, especially for manipulating/processing data.

CurveExpert is very easy to use if you again use the mouse highlight feature to move the data from Excel through a Cut and Paste procedure.

You may save the results on the computer if you create a subdirectory with your lab section identified. Copying the data to floppy disk is also a good idea.