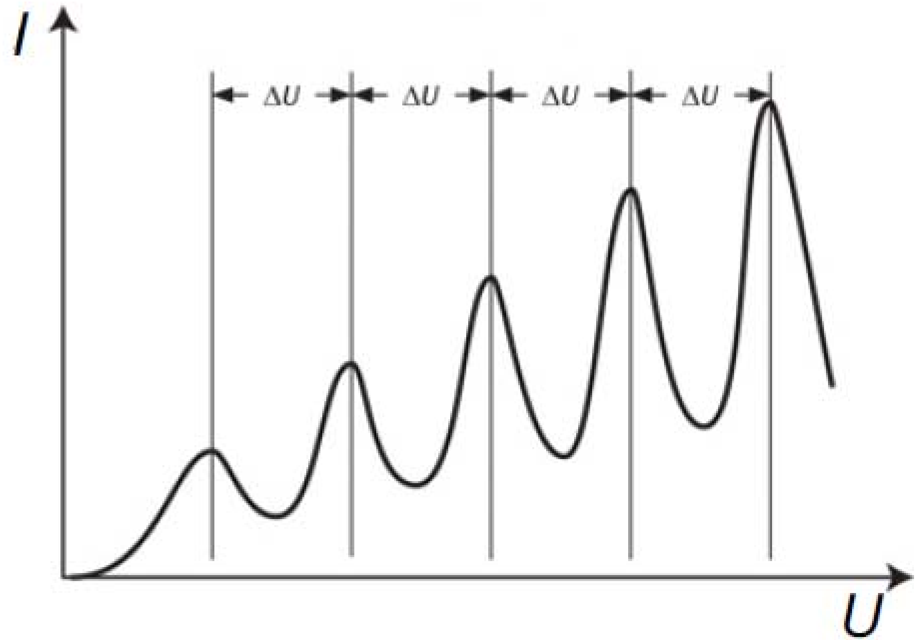
The Franck-Hertz Experiment



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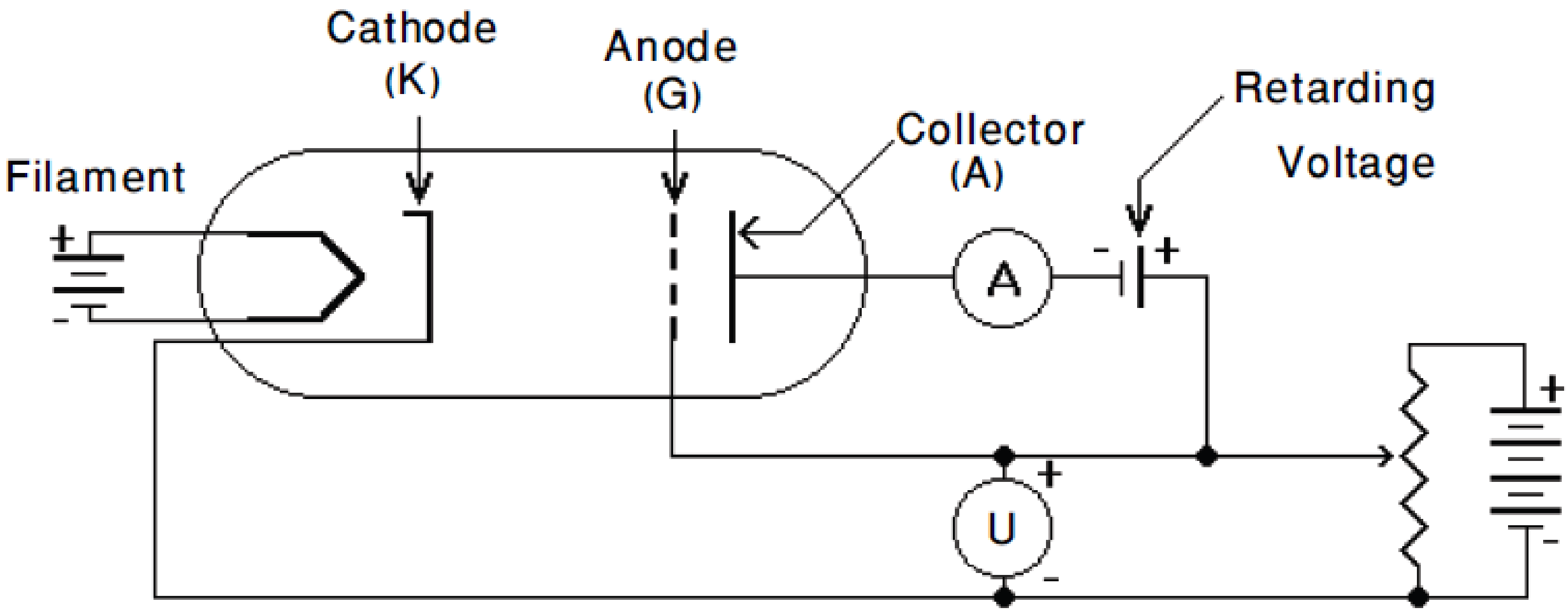
The Franck-Hertz Experiment

- First performed in 1914 by James Franck and Gustav Ludwig Hertz to probe Bohr’s hypothesis of quantized atomic structure.
- Winner of the 1925 Nobel Prize in physics for its contribution toward the understanding of physics.
- Profound results from a simple setup.

The Setup


Cathode
(K)
Anode
(G)
Collector
(A)
Retarding
Voltage
Filament
+
-
A
-
+
+
U
+
-
-

Objectives

The experiment is relatively more conceptual in its content. Students will

- *interpret* experimental observations in a rigorous way.
- be exposed to investigative reasoning and appreciate its importance in science
- understand the profound connection between thermal and quantum physics.

Theoretical foundations

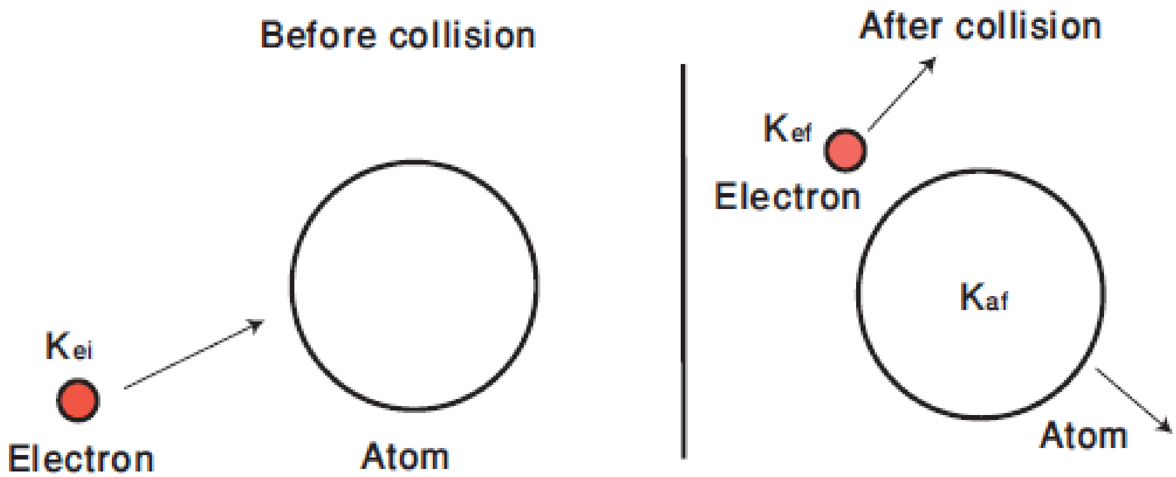
Elastic collisions

Kinetic energy of the system of colliding entities is conserved.

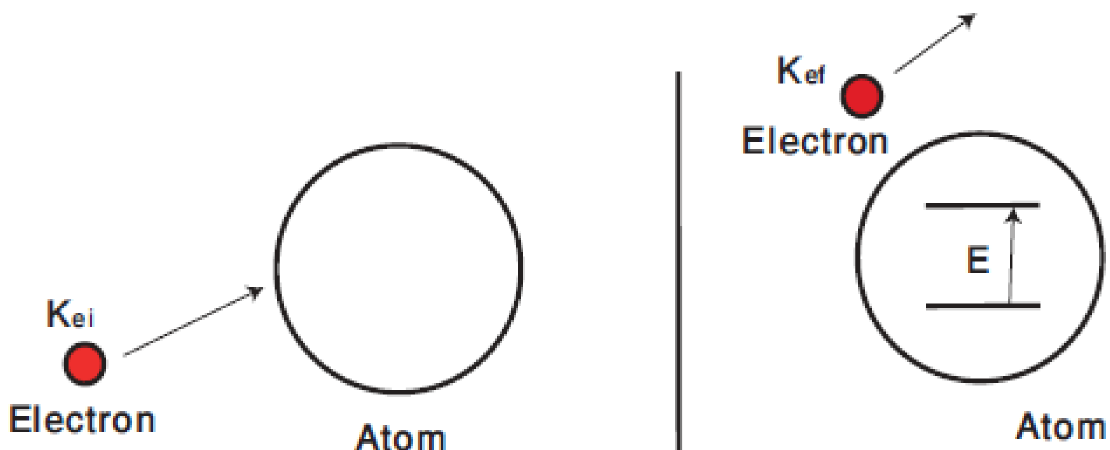
Inelastic collisions

A part of the kinetic energy is dissipated as a change in the internal energy of the colliding entities.

Elastic/Inelastic collisions



Elastic collision: $K_{ei} = K_{ef} + K_{af}$

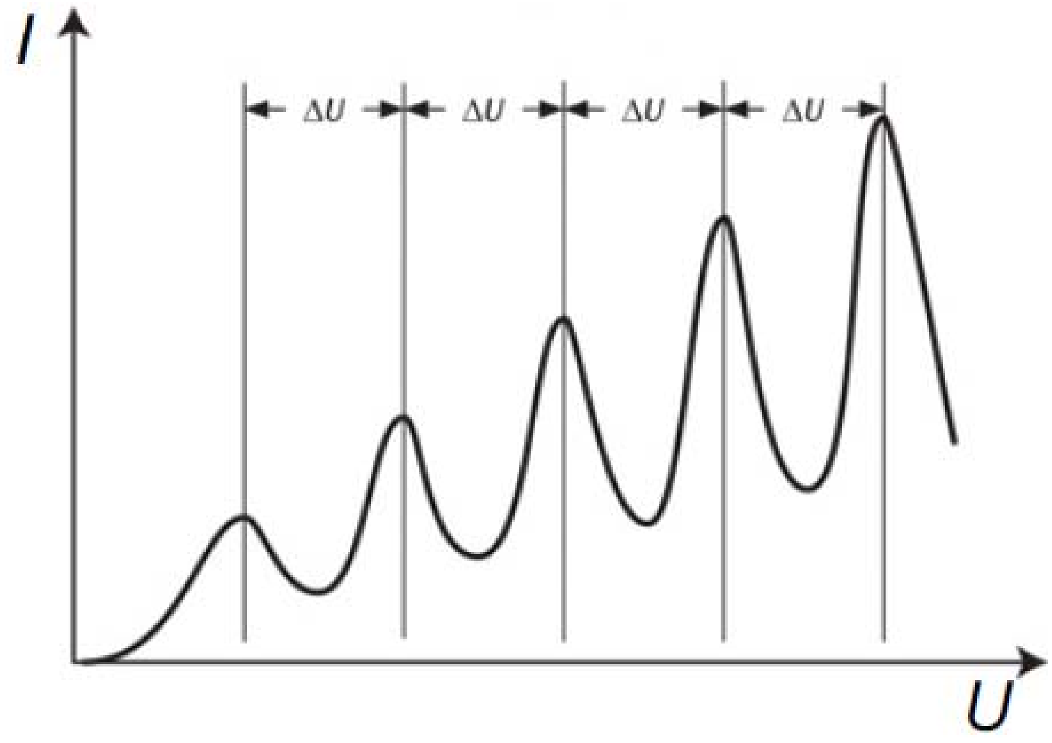


Inelastic collision: $K_{ei} = K_{ef} + E$

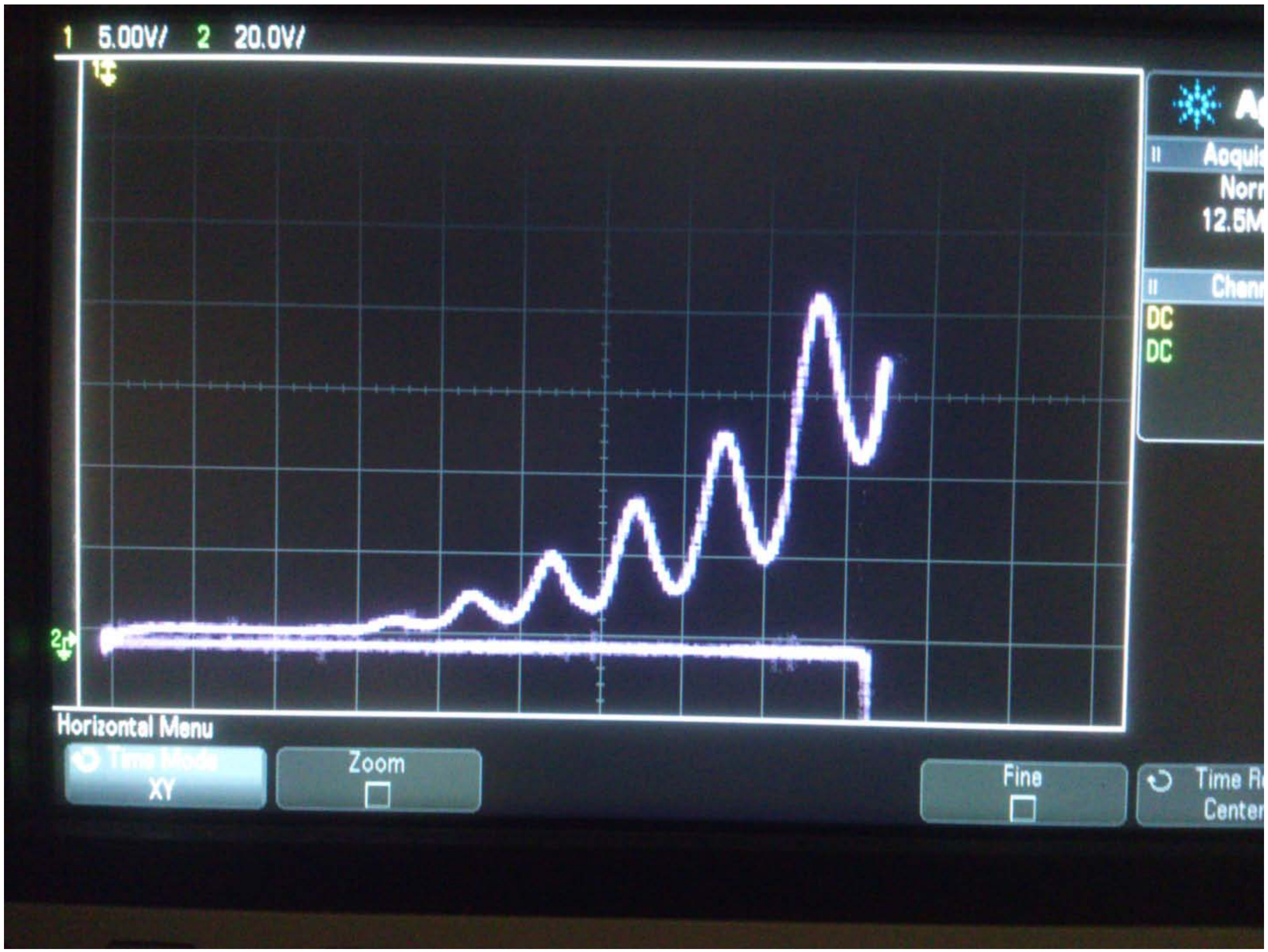
Experimental scheme

- Anode (accelerating) voltage is increased and resulting variations in collector current are measured.
- An X-Y trace on the oscilloscope shows a graph between the accelerating voltage (on x-axis) and collector current (on y-axis).
- Temperature is measured using a thermocouple inside the oven.

The Franck-Hertz Curve



The Franck-Hertz Curve



The Franck-Hertz Curve

- *Periodic dips in current*

  - due to electrons colliding inelastically with mercury atoms.

  -The gap between the two dips equals the first excitation potential of mercury.

- *Variation in the height of current minima*

  - due to the mean-free-path variation of electrons

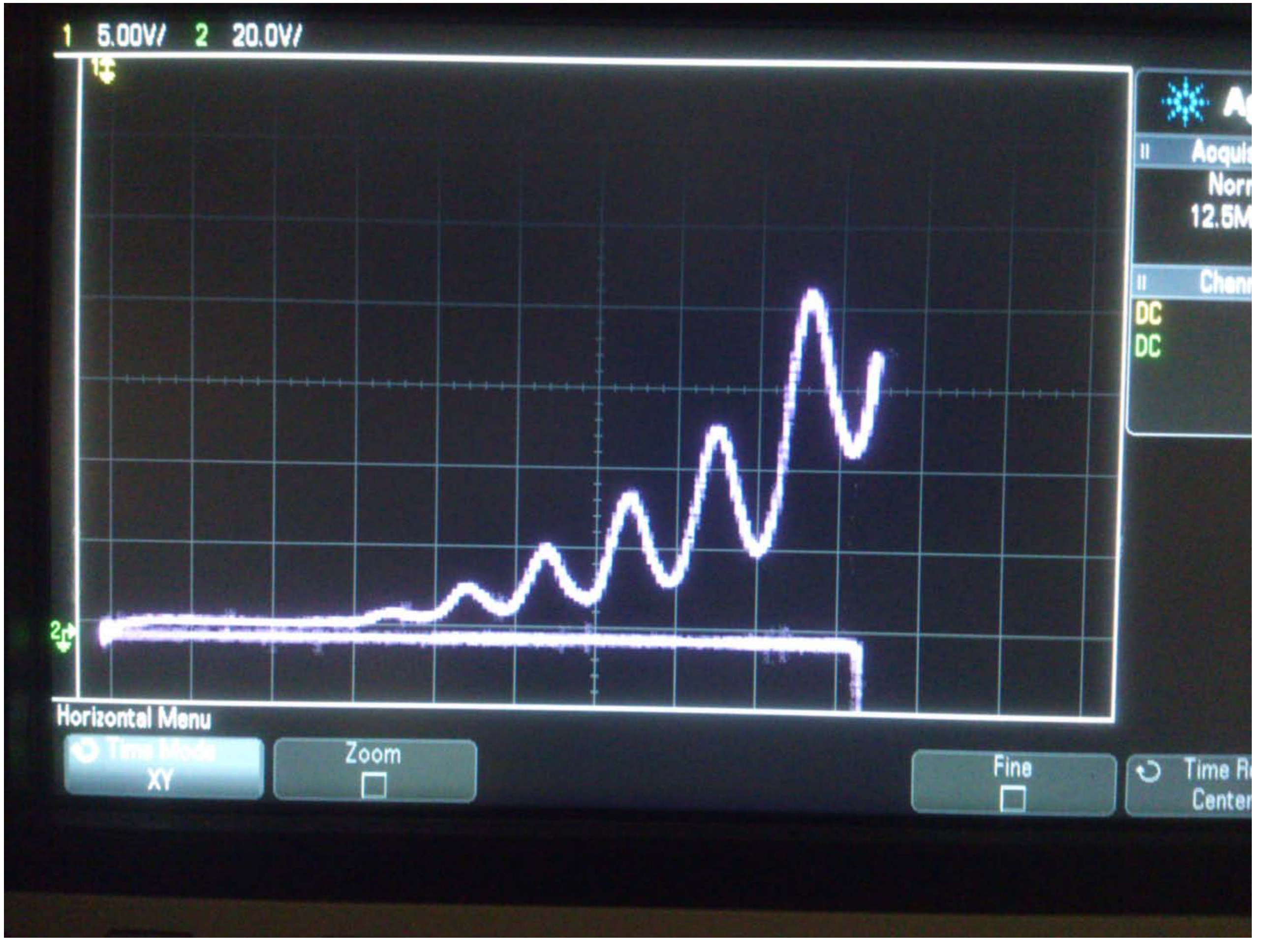
Temperature dependence

- Heating up the tube is necessary to maintain a vapor pressure of mercury, which is highly sensitive to temperature.

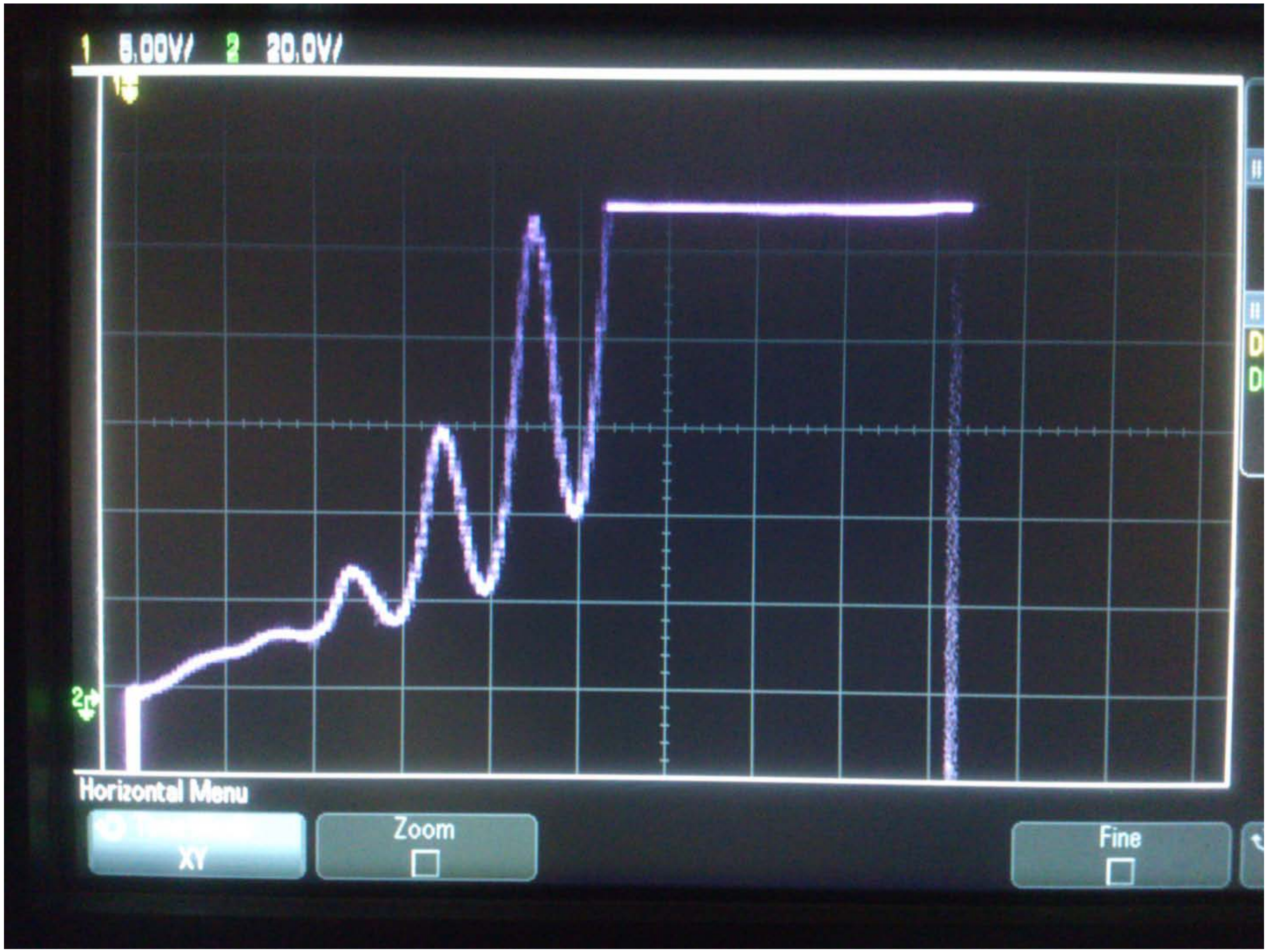
$$P = 8.7 \times 10^{(9-(3110/T))}$$

- Temperature changes affect the shape of the Franck-Hertz curve.
- This is due to the variations in mercury vapor pressure (or the number density of mercury atoms)

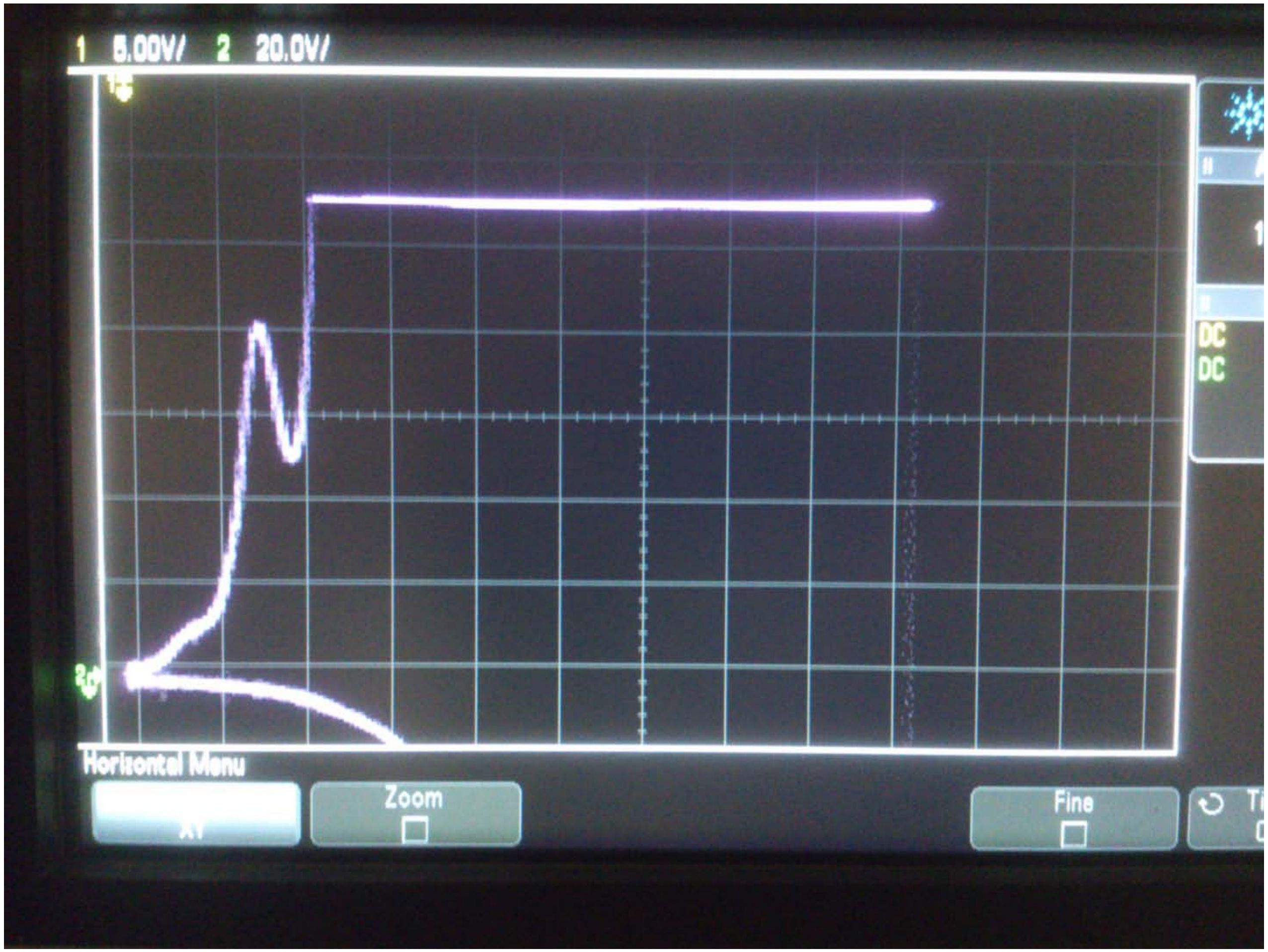
Temperature = 170 ^oC



Temperature = 140 ^oC



Temperature = 110 ^{o}C



Temperature = 100 ^oC

Mean Free Path calculation

$$PV = nRT$$

$$R = N_A k_B$$

$$PV = nN_A k_B T = Nk_B T$$

$$N' = N/V$$

$$N' = \frac{P}{k_B T} \qquad \lambda = \frac{1}{N'\sigma}$$

Thank You!

Questions?