Franck Hertz experiment

By : Muzamil Shah

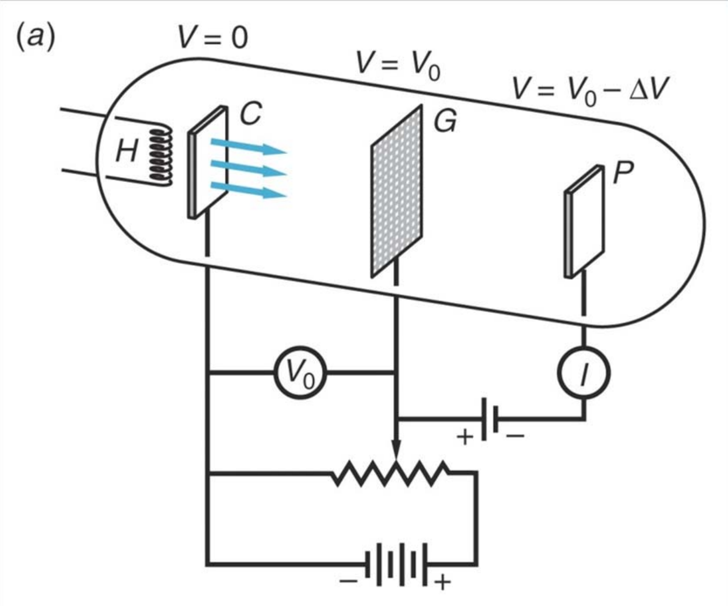
Preview of Things to Come

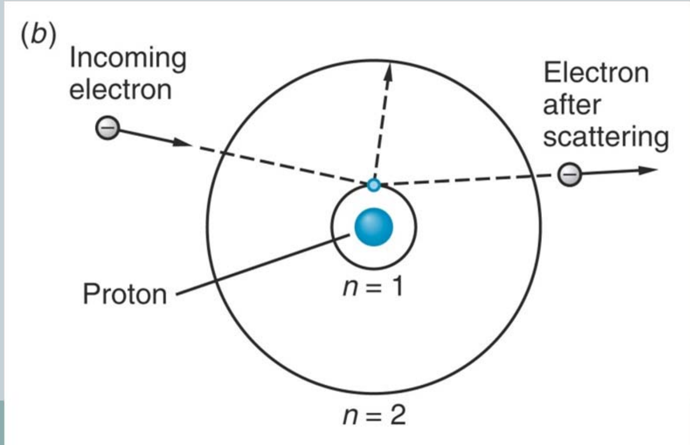
- History
- Theory
- Setup
- Results
- Conclusions

History

- In 1914, by James Franck and Gustav Ludwig Hertz
- One year after Bohr's theory of quantized energy states
- Nobel Prize in 1925: "for their discovery of the laws governing the impact of an electron upon an atom"

Theory





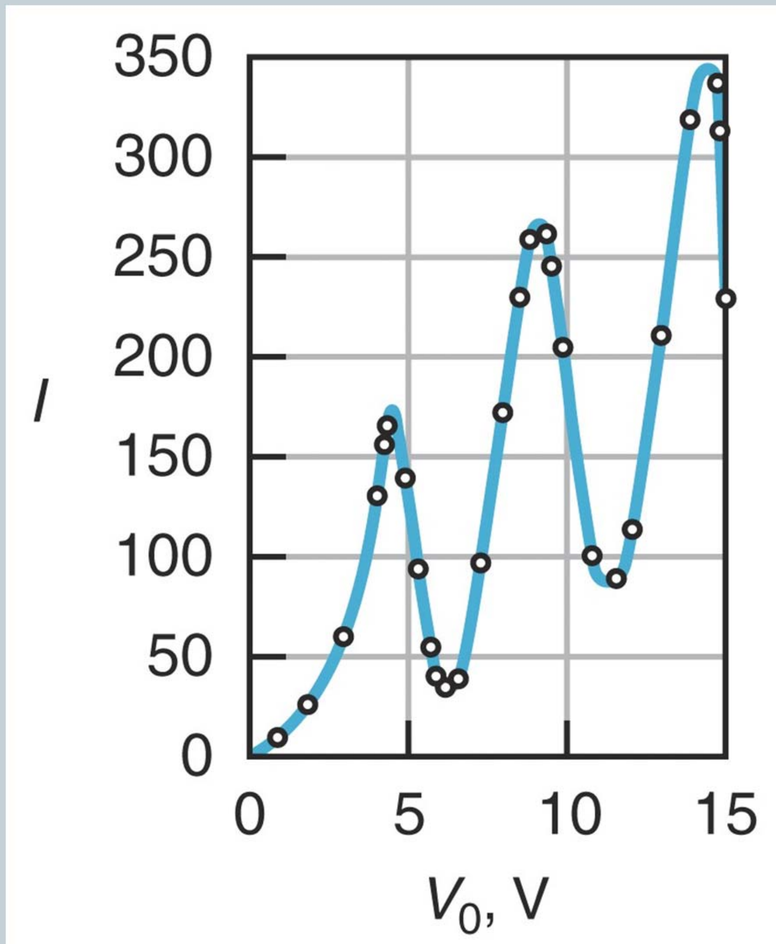
Inelastic scattering of electrons
Confirms Bohr's Energy quantization

Electrons ejected from heated cathode at zero potential are drawn towards the positive grid G. Those passing through hole in grid can reach plate P and cause current in circuit if they have sufficient kinetic energy to overcome the retarding Potential between G and P

Tube contains low pressure gas of stuff!

If incoming electron does not have enough energy to transfer $\Delta E = E_2 - E_1$ then Elastic scattering, if electron has at least KE= ΔE then inelastic scattering and the electron does not make it to the plate P
→ Loss of current

Theory



Current decreases because many
Electrons lose energy due to inelastic
Scattering with the Hg atom in tube
And therefore can not overcome the
Small retarding potential between
G → P

The regular spacing of the peaks
Indicates that ONLY a certain quantity
Of energy can be lost to the Hg atoms
ΔE=4.9 eV.

This interpretation can be confirmed by
Observation of radiation of photon energy
E=hf=4.9 eV emitted by Hg atom when
$V_0 > 4.9$V

Theory

For n inelastic collisions the energy gained by the electrons is

$$E_n = n(E_a + \delta_n) \, .$$

Where Ea is the lowest excitation energy and δ_n is additional energy

The spacing between two minima in a Franck-Hertz curve is given by

$$\Delta E(n) = E_n - E_{n-1} = \left[1 + \frac{\lambda}{L}(2n-1) \right] E_a \, .$$

The mean free path of the electrons can be written as

$$\lambda = \frac{L}{2E_a} \frac{d\Delta E(n)}{dn} \, .$$

Theory

Theoretically mean free path is given by

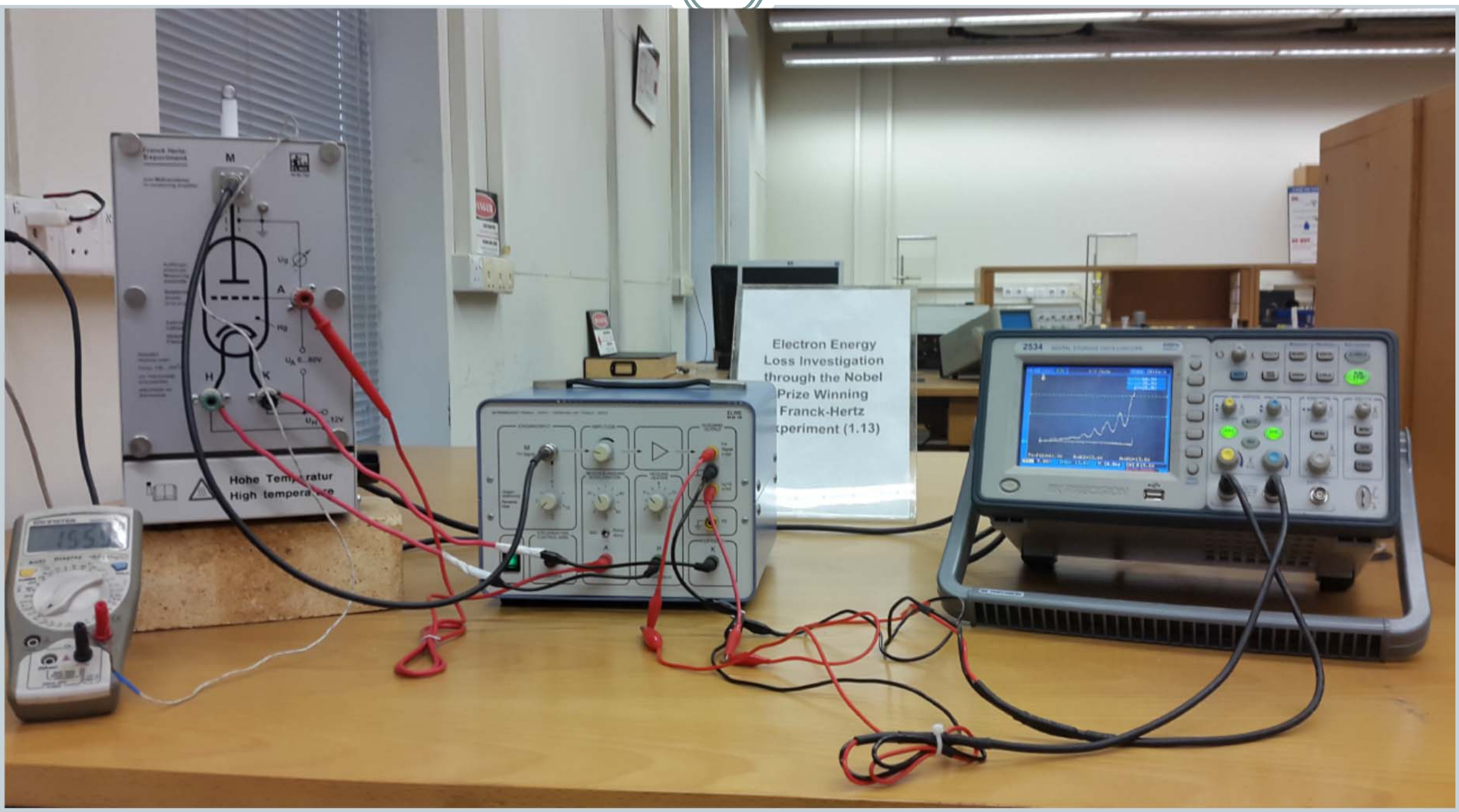
$$\lambda = \frac{1}{N\sigma} = \frac{k_B T}{p\sigma},$$

where is the cross section for inelastic collisions

In the temperature range from 300 to 500 K the mercury pressure *p* is given as

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

Setup of Frank-Hertz Experiment



Experimental data

Temp	145 C			
n	1	2	3	4
Ea (eV)	4.4	4.8	5.2	6

Temp	150 C				
n	1	2	3	4	5
Ea (eV)	4.8	5.2	5.6	5.6	6

Temp	155 C					
n	1	2	3	4	5	
Ea (eV)	4.4	4.8	5.2	5.6	6	

Temp	160 C					
n	1	2	3	4	5	6
Ea (eV)	4	4.8	5.2	5.6	5.2	6

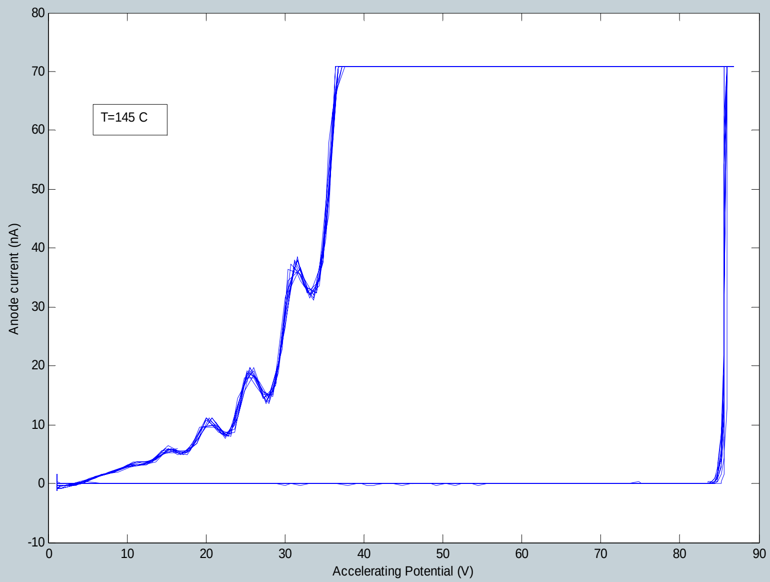
Temp	165 C						
n	1	2	3	4	5	6	7
Ea (eV)	4.8	5.2	5.2	5.6	5.2	5.6	6

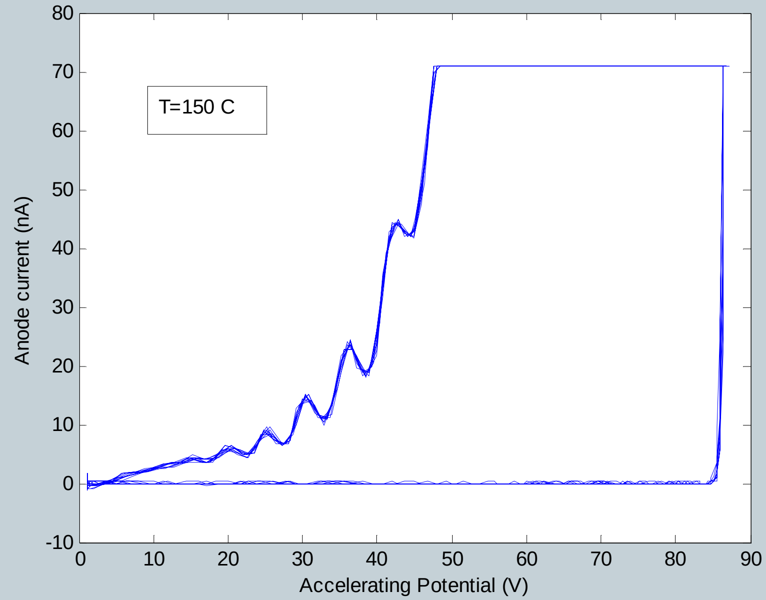
Temp			170				
n	1	2	3	4	5	6	7
Ea (eV)	4.4	4.8	5.2	5.2	5.6	5.6	6

Experimental data

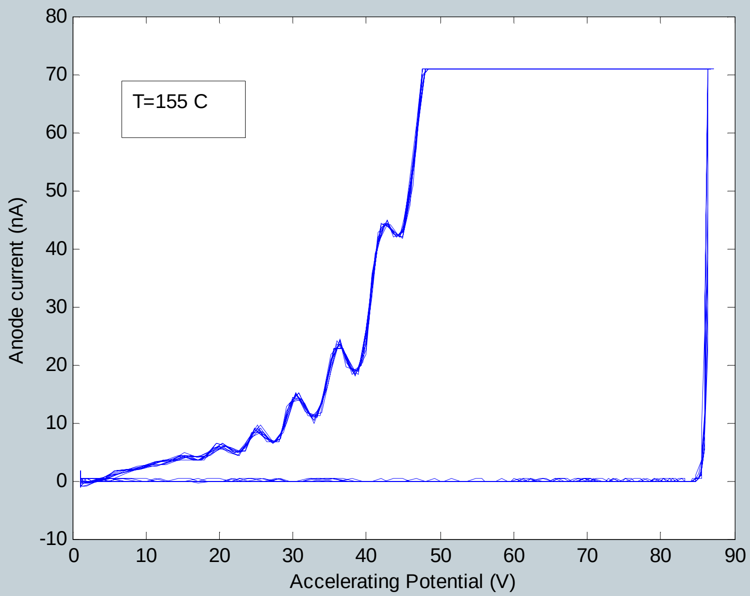
T (K)	Ea (eV)	Lambda (micro meter) Experimental	Lambda (micro meter) Theoretical	Slope (eV)
145	4.20	333.33	243.59	0.52
150	4.74	206.75	201.32	0.28
155	4.20	333.33	167.15	0.40
160	4.14	279.00	139.39	0.33
165	4.41	190.48	116.74	0.24
170	4.88	71.72	98.17	0.10

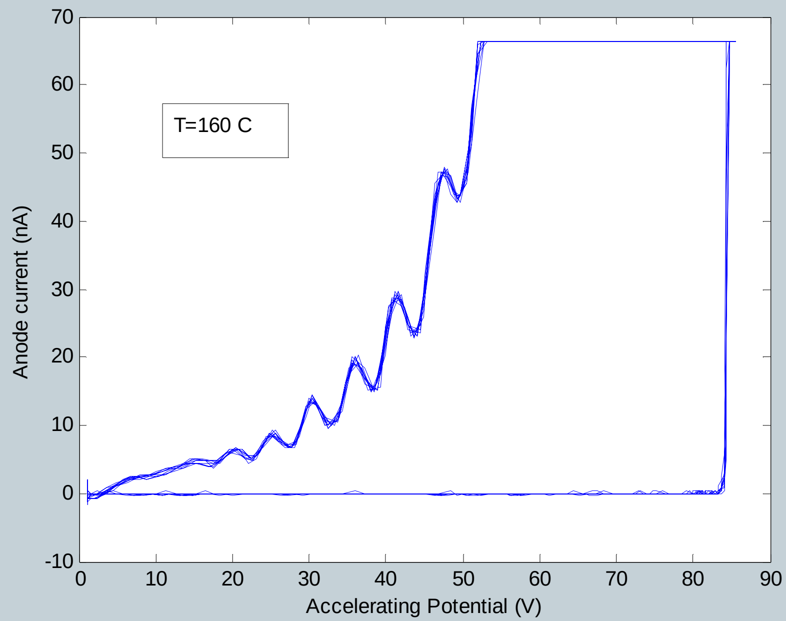
Result of Frank-Hertz Experiment



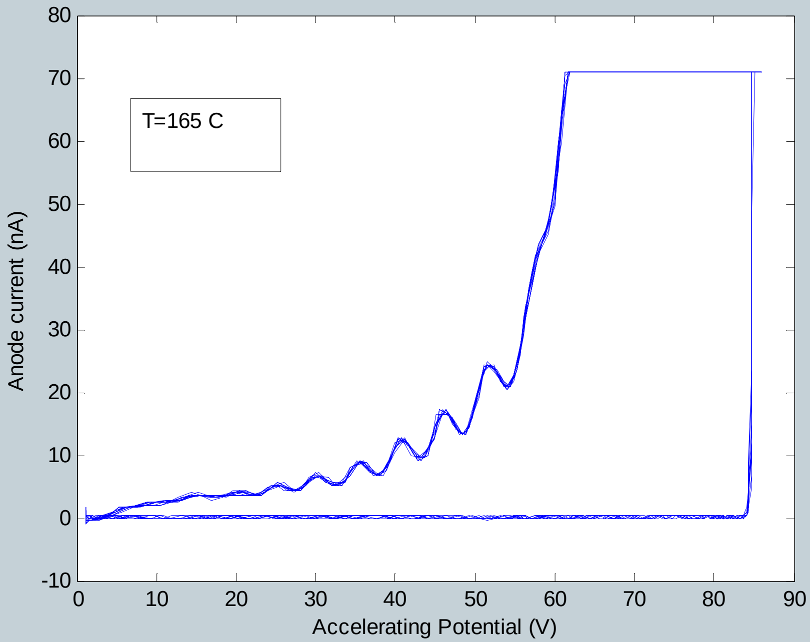


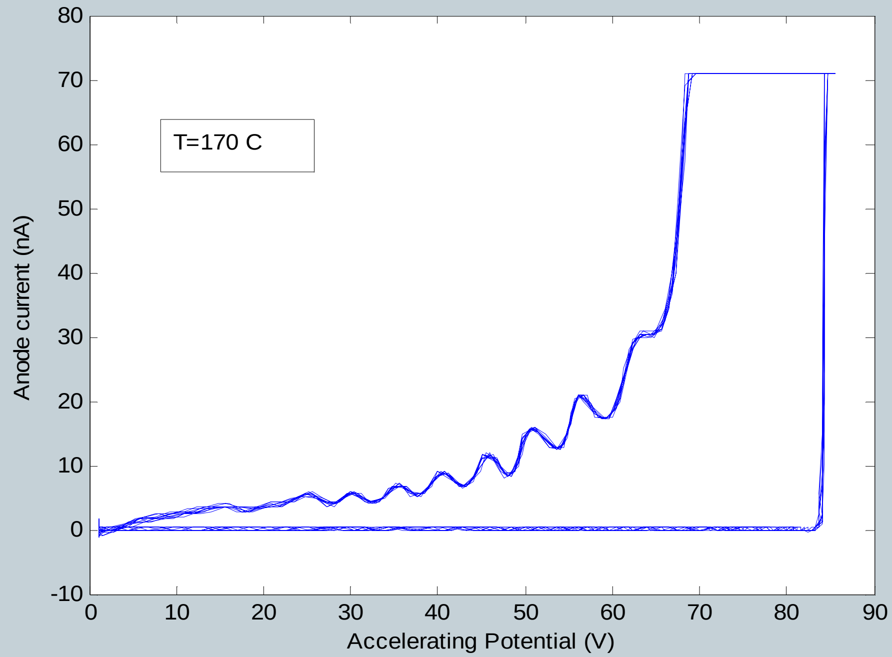
Result of Frank-Hertz Experiment



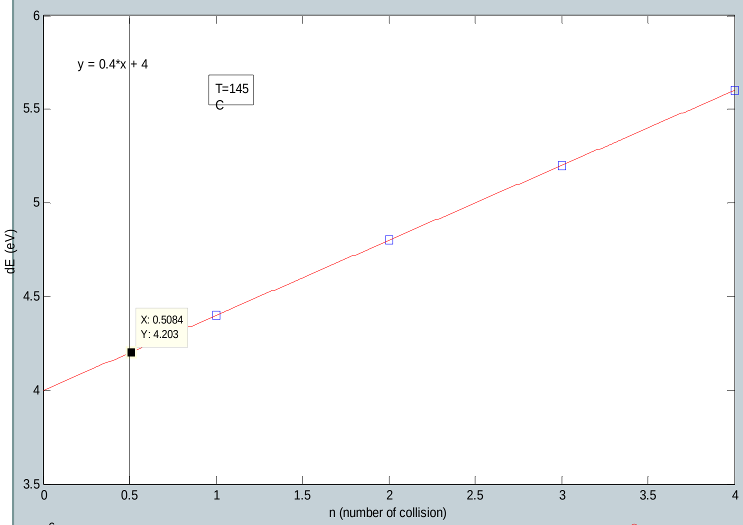


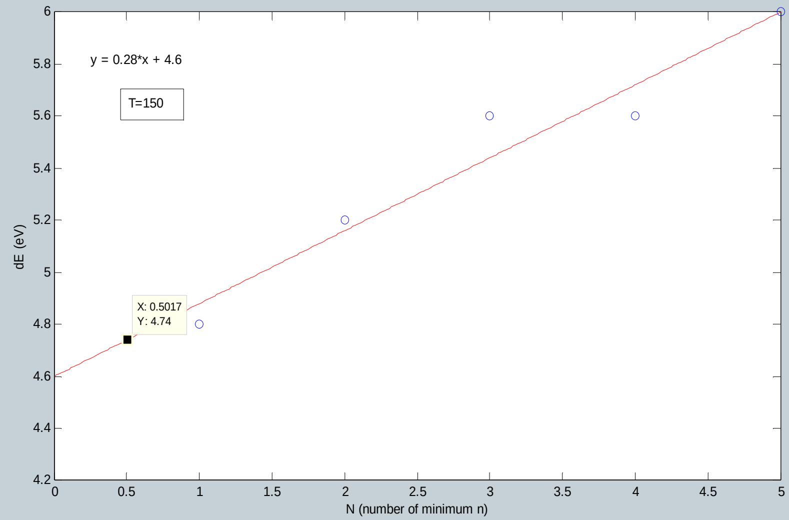
Result of Frank-Hertz Experiment

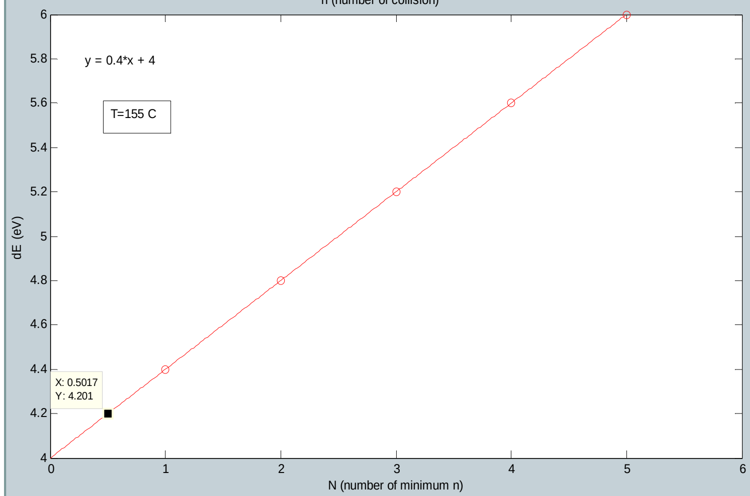


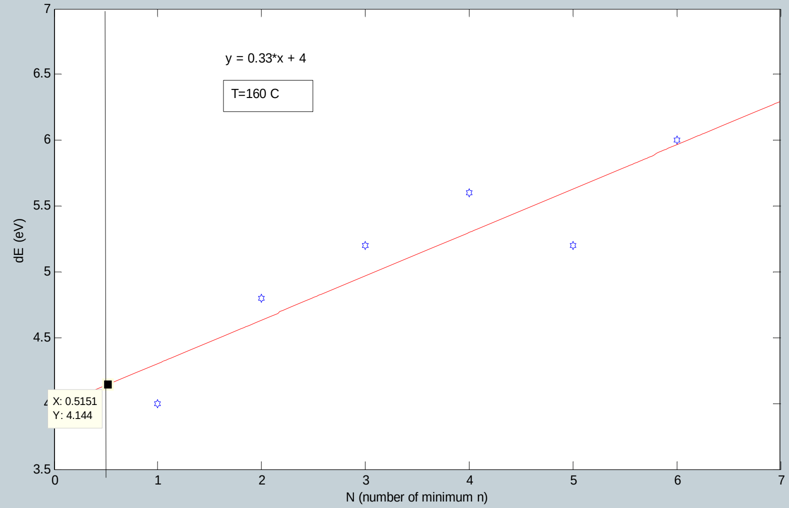


Spacing ΔE vs. n

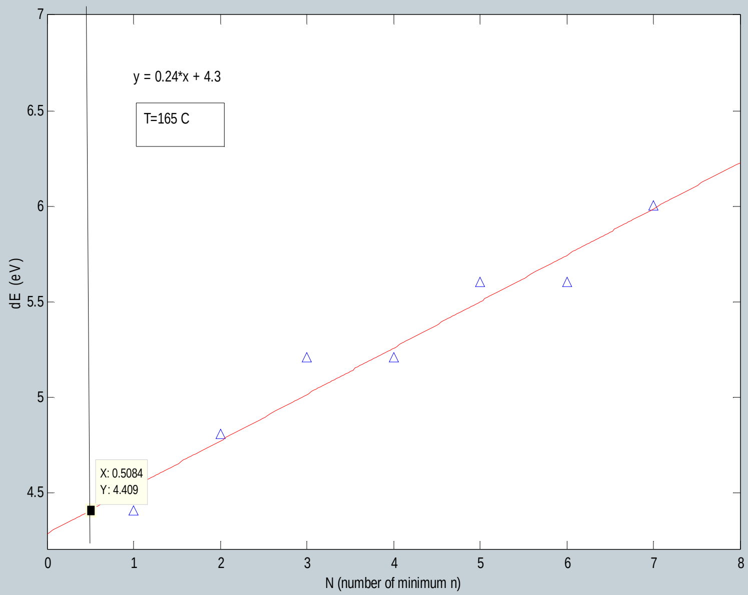


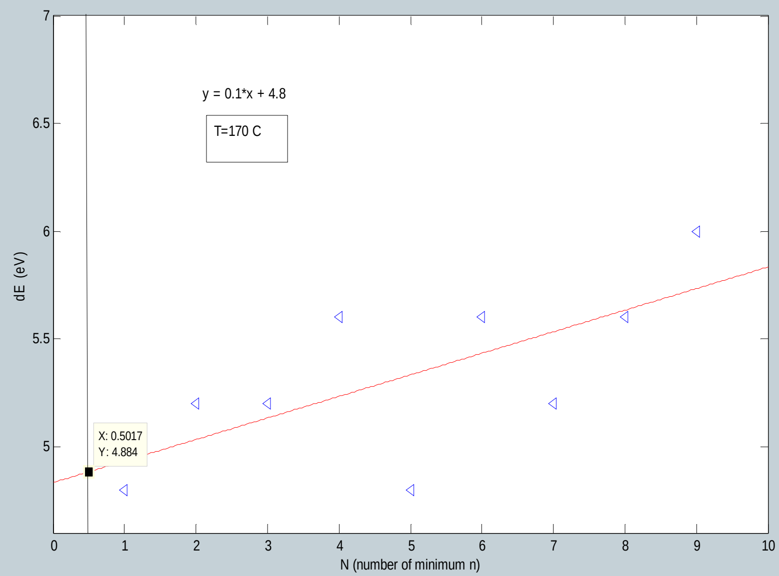




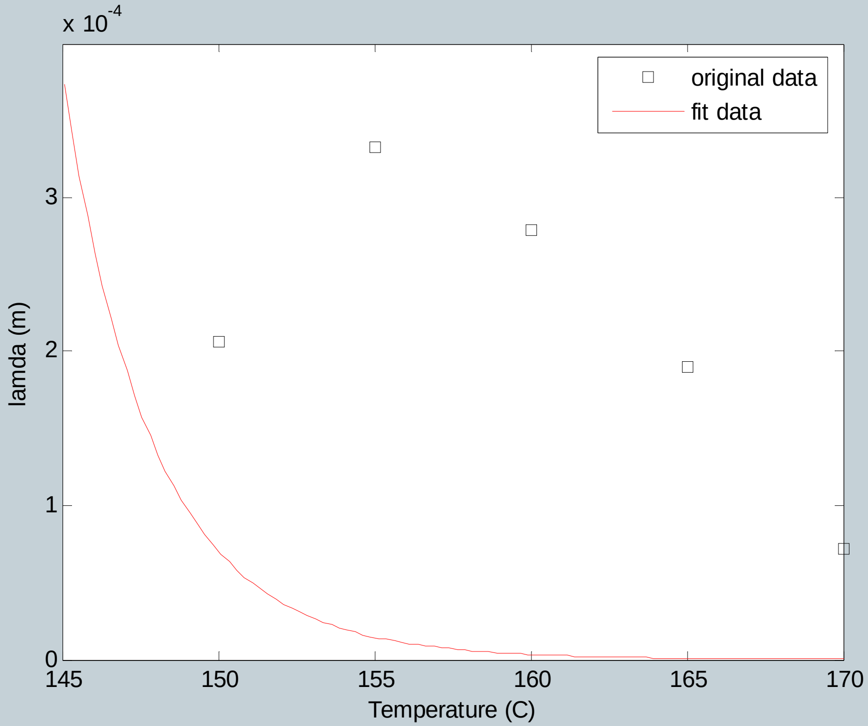


Spacing ΔE vs. n

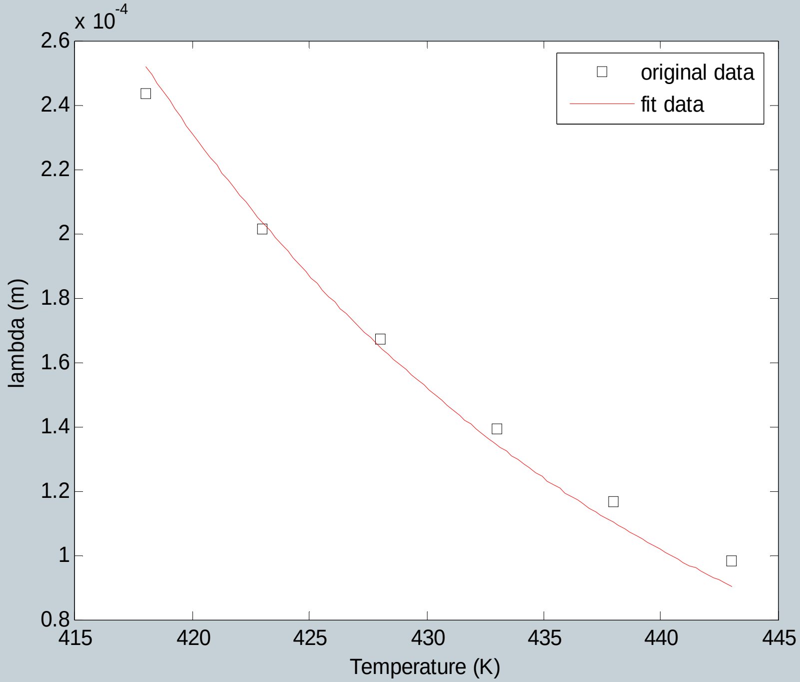




Lambda vs. T



Experimental data



Theoretical data

CONCLUSIONS:

•Electrons with certain specific energies were not passing through the tube. If the electrons had energies:

- < 4.9 eV they bounced off the mercury atoms with no loss of energy and continued to the anode
- = 4.9 eV they collided with mercury atoms and transferred all of their energy to the atom and did not reach the anode (causing the current to drop)
- > 4.9 eV that collided with atoms gave up 4.9 eV of energy, but sill have some energy left to travel to the anode

Thanks