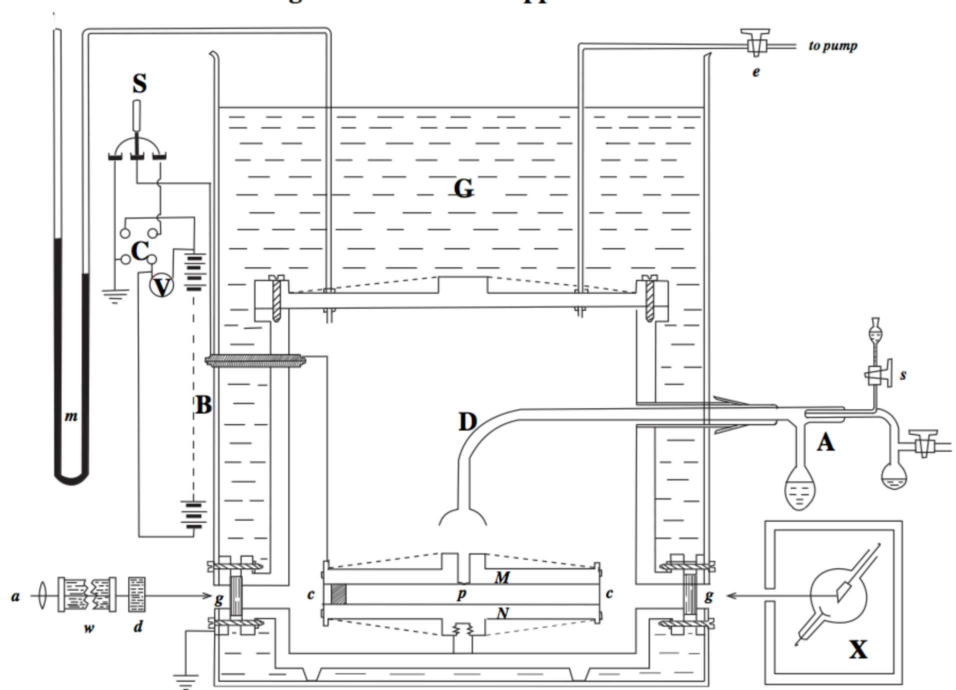
The Millikan Oil Drop Experiment

Diagram of Millikan's Apparatus[7]



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Overview

- Historical Overview
- Theory and Apparatus
- Method
- Results
- Discussion
- Conclusion

Historical Overview

- First records of the effects of electricity are credited to the Greeks
- Ben Franklin proposed in 1747 first explanation of these electric phenomena
  - Proposed that a fluid-like substance was responsible for electric effects
  - Additionally proposed the existence of electricity as existing in particle form

Historical Overview

- At the turn of the century the first reasonably accurate measurements of the charge of the electron were made
  - J. S. Townsend: 3E-10 e.s.u.
  - J. J. Thompson: 6E-10 e.s.u.
  - H. S. Wilson 3E-10 e.s.u.
- Millikan's experiment improved upon Wilson's in that it allowed for the measurement of a single drop of charged fluid (oil)

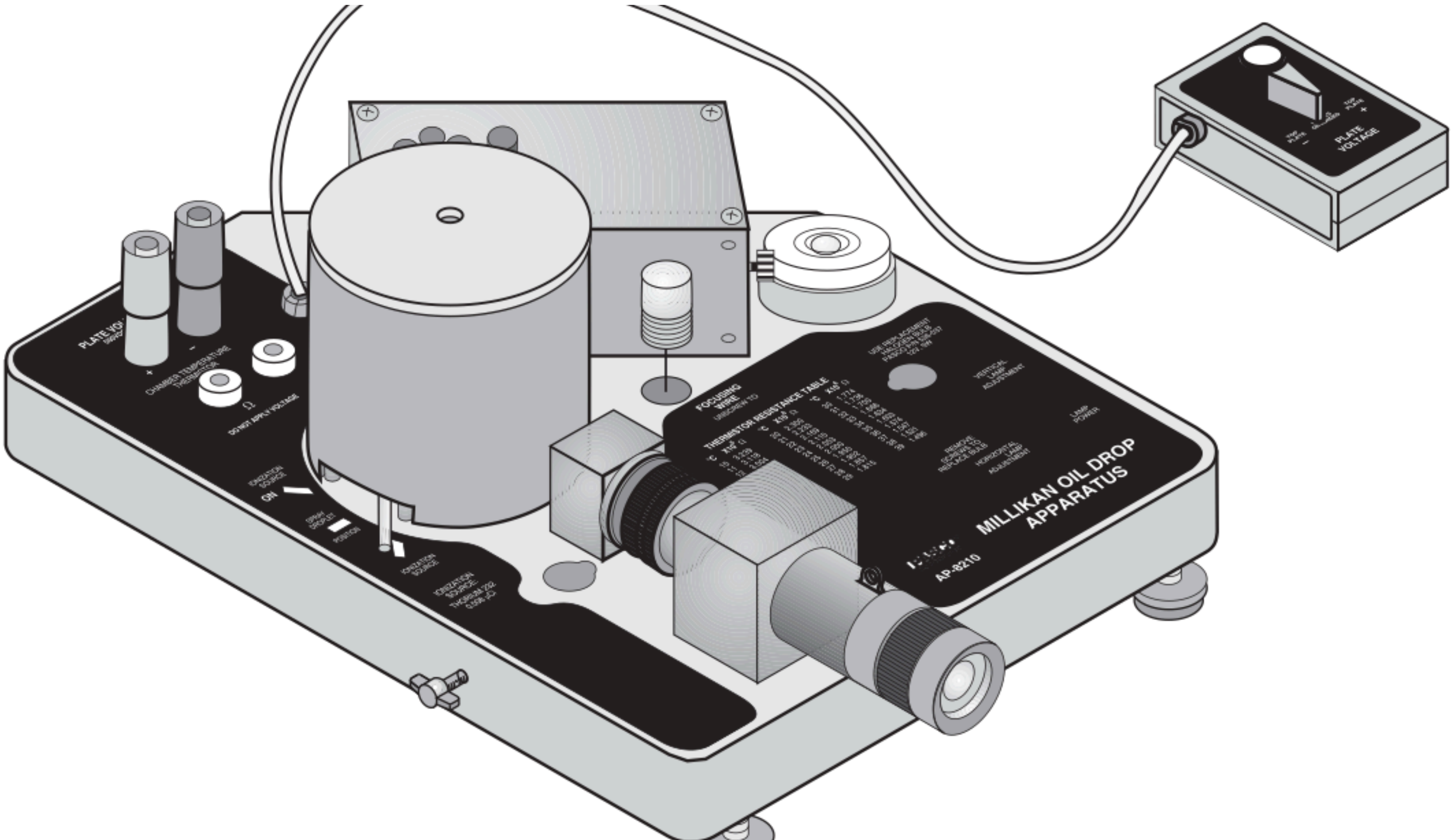
Theory and Apparatus

- Basic Ideas behind Millikan's experiment
  - Place a charged drop of oil simultaneously in parallel/anti-parallel gravitational and electric fields
  - Observe how these fields interact with the drop – i.e. observe how quickly the drop rises and falls.
  - If you know the size and mass of the drop, how much air resistance it experiences, and the strength of the fields, these rising and falling velocities will give you the drop's excess charge.

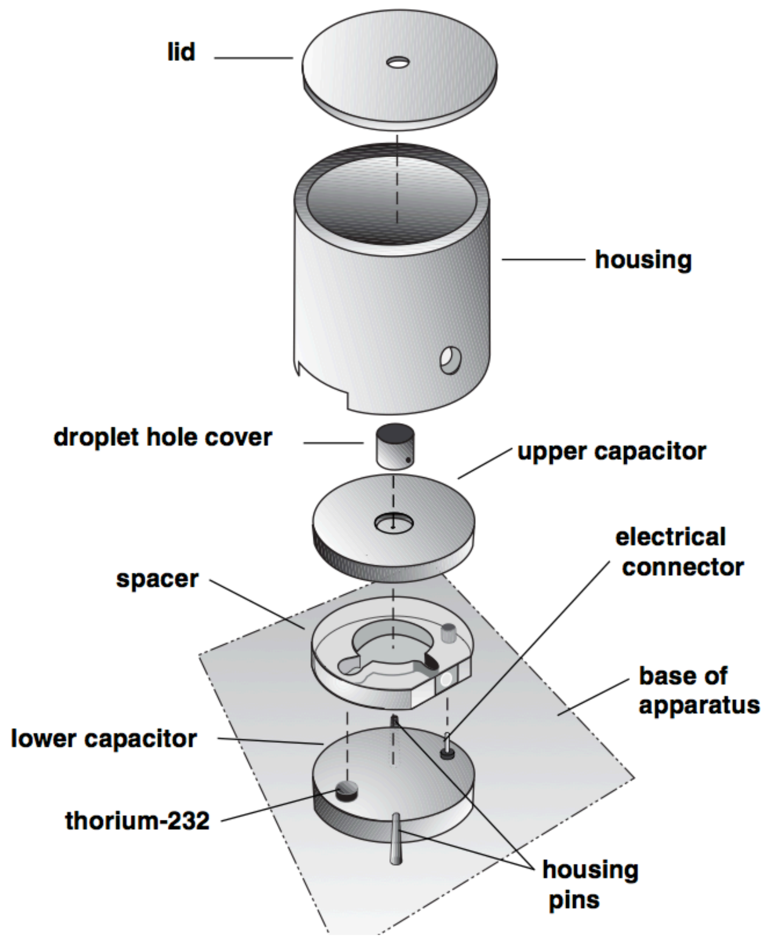
Theory and Apparatus

- Basic ideas behind Millikan’s experiment
  - By comparing recorded oil drop charges with integer multiples of the smallest recorded oil drop charge, the quantization should be apparent
  - Using this smallest recorded oil drop charge value in conjunction with other larger recorded values (which presumably occur in near integer multiples of the smallest recorded value) the charge of the electron can be calculated.

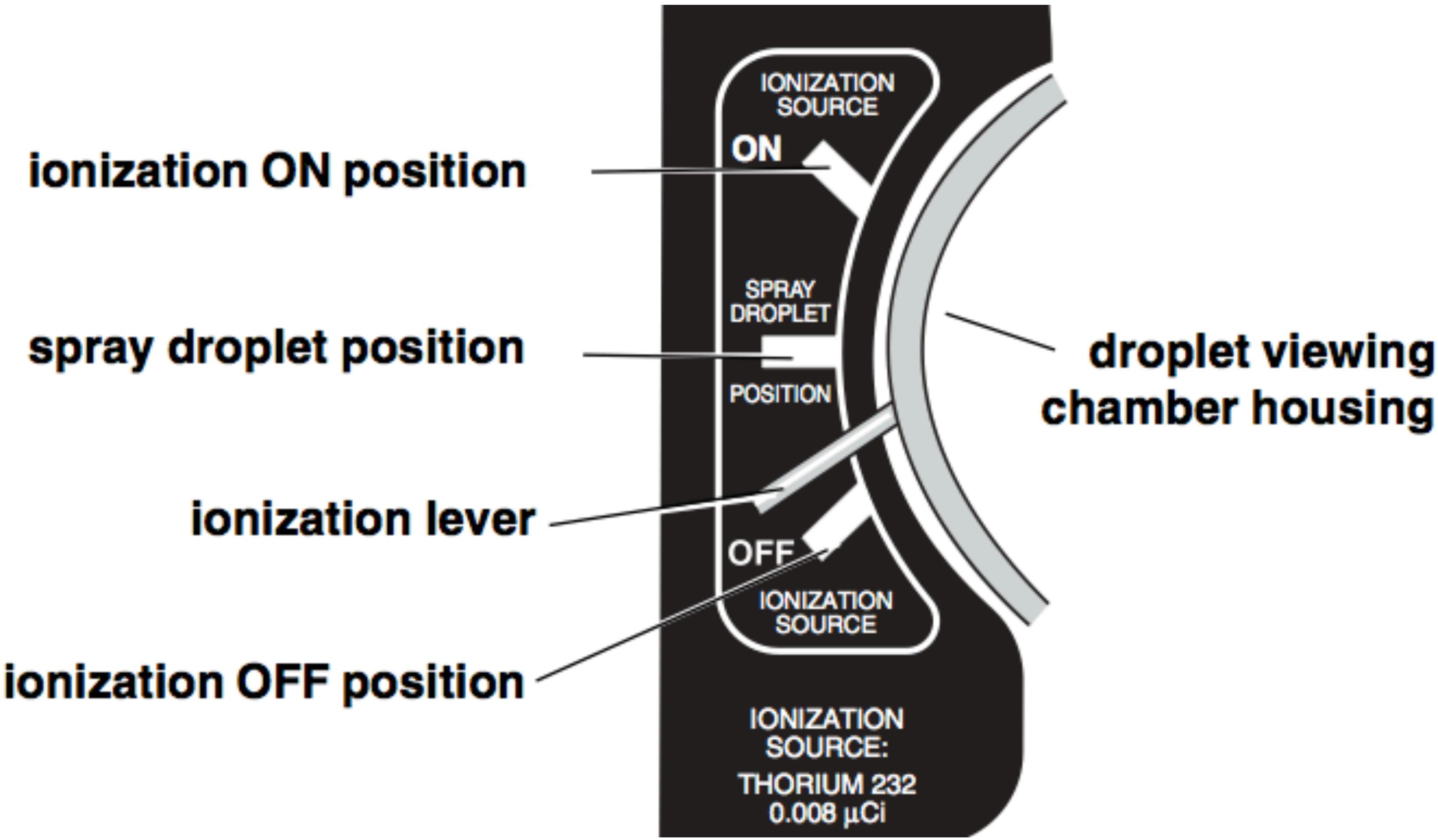
Theory and Apparatus



Theory and Apparatus



Theory and Apparatus



Theory and Apparatus

- Taking the aforementioned conceptual description of the experiment into account with the specificities of the apparatus the following equation for the charge of a drop may be derived :

$$q = \left[400\pi d \left(\frac{1}{g\rho} \left[\frac{9\eta}{2} \right]^3 \right)^{1/2} \right] x \left[\left(\frac{1}{1 + \frac{b}{pa}} \right)^{3/2} \right] x \left[\frac{\nu_f + \nu_r \sqrt{\nu_f}}{V} \right] \text{e.s.u.}$$

- Such that…

Sources

- Pasco Millikan Oil Drop Apparatus Manual, Scientific model AP-8210
- Wikipedia, en.wikipedia.org/wiki/electron
- Wikipedia, en.wikipedia.org/wiki/Benjamin_Franklin

Theory and Apparatus

- Eta = the viscosity of the air within the viewing chamber (Na/m^2)
- d = the distance between plates (m)
- rho = density of the oil (kg/m)
- g = the acceleration of gravity (m/s^2)
- b = constant = 8.2E-3 (Pa*m)
- p = pressure (Pa)
- a = drop radius (m)
- V = voltage between the plates
- vr = rising velocity of a drop
- vf = falling velicity of a drop

Method

- 1) After finding a drop which moved with a workable speed, the velocity of that drop was recorded for grounded and charged plates; five measurements of each case were taken.
- 2) After five measurements the ionization lever was switched on and then off.
- 3) If the drop was still visible five more measurements were taken. This was repeated for 25 separate drops.

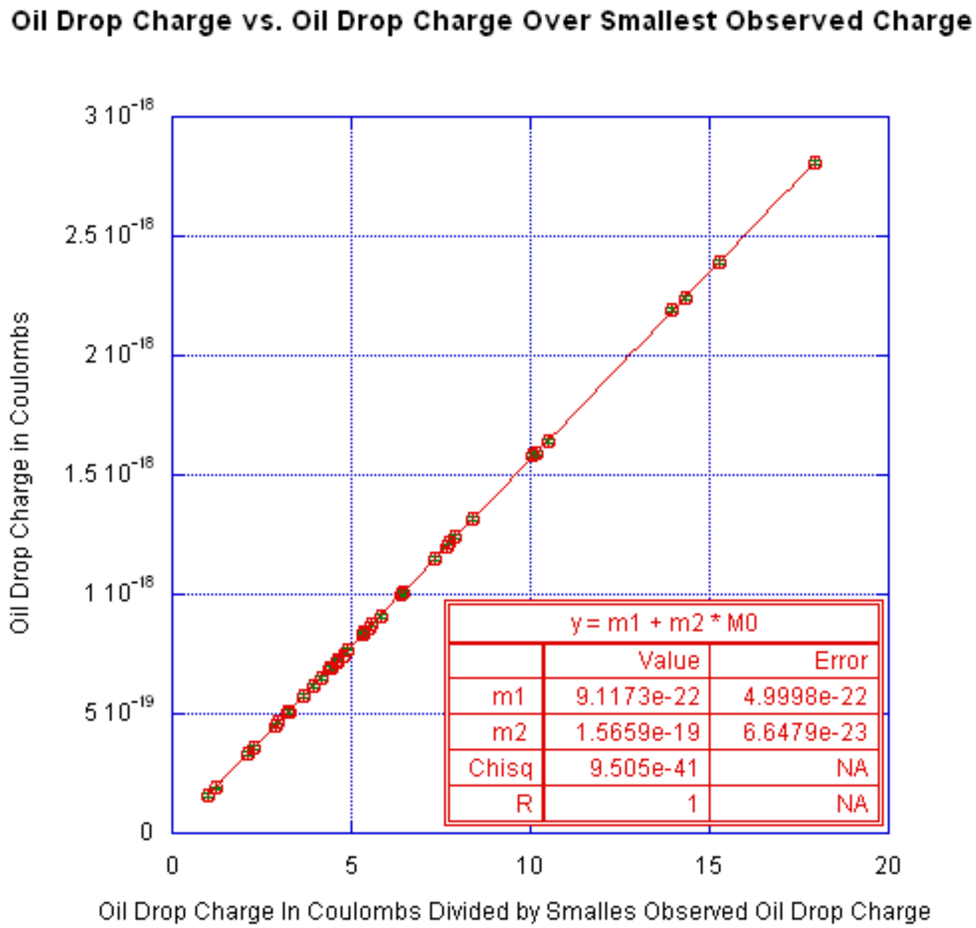
Method

- Note:
  - Each measurement of a rising velocity was preempted by a measurement of the falling velocity.
  - Since the falling velocity holds information about the size and mass of a given drop, this pairing of data corrected for possible, spontaneous changes in radius or mass of a drop being observed.

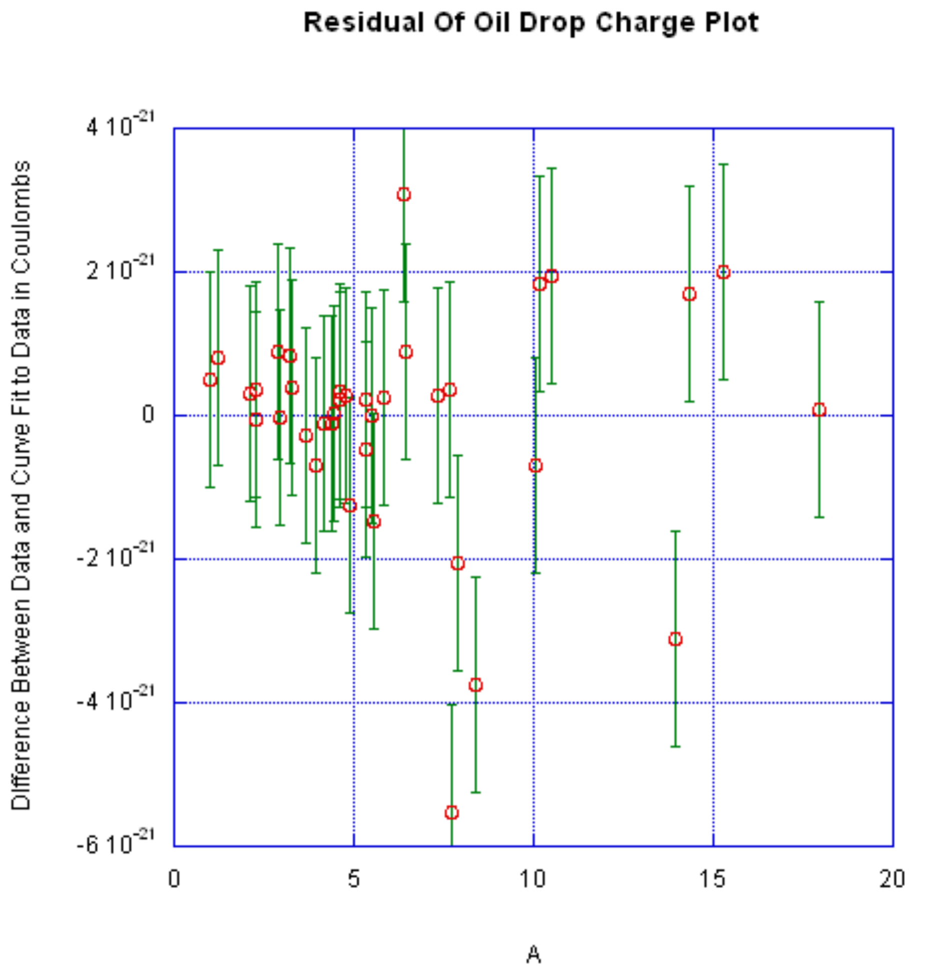
Results

- Calculated Value of e: 1.5659 E-19 (+-) 7 E-23 Coulombs
- Accepted value: 1.60217646 E-19 coulombs
- Discrepancy: about two percent

Results


Oil Drop Charge vs. Oil Drop Charge Over Smallest Observed Charge
3 10^-18
2.5 10^-18
2 10^-18
1.5 10^-18
1 10^-18
5 10^-19
0
Oil Drop Charge in Coulombs
0
5
10
15
20
Oil Drop Charge In Coulombs Divided by Smalles Observed Oil Drop Charge
y = m1 + m2 * M0
Value
Error
m1
9.1173e-22
4.9998e-22
m2
1.5659e-19
6.6479e-23
Chisq
9.505e-41
NA
R
1
NA

Results


Residual Of Oil Drop Charge Plot
Difference Between Data and Curve Fit to Data in Coulombs
4 10-21
2 10-21
0
-2 10-21
-4 10-21
-6 10-21
0
5
10
15
20
A

Discussion

- Difficulties:
  - Observing a drop with only one excess charge
  - Keeping track of drops in between ionization steps
  - Keeping track of drops among a large crowd of drops
- Possible Solution
  - Make the viewing chamber larger
    - This would provide for a larger field of view though which the viewing chamber could be seen.

Discussion

- Quantization:
  - Looking at the first graph under the Results section, data points appear to be grouped around integer numbers of the smallest observed charge. This supports the **model** that, in nature, electrical charge is quantized.
- Measurement of e:
  - The value obtained from this experiments data is within two percent of the currently accepted value. This supports the current **model** that all electrons carry the same electric charge.

Conclusion

- The experimental data support that electric charge is quantized in nature given the linear nature of the first graph under the Results section and the grouping of data points around integer values of the smallest measured charge. The calculated value of e is also in fairly good agreement with the accepted, current value.

Conclusion

- The major difficulties in this experiment were in taking data and specifically observing singular drops move with different charges – a larger viewing chamber would help this to ameliorate this problem.