MILLIKAN'S OIL DROP EXPERIMENT

EXPERIMENTAL REPORT

ABSTRACT

In this report is discussion of the results of Millikans Oil Drop Experiment, in which an electric field was used to apply a calculable force onto droplets of oil. This report aims to determine whether that force, and its attendant electric charge, falls into integer multiples of some common force, which would indicate a fundamental, indivisible charge; the electron.

The charge found in this report was not consistent with the common accepted value for the charge on an electron.

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Introduction

The accepted model of the electron posits that the electron is an individual particle with a particular charge common to all electrons. If true, the charge on that electron should be determinable by determining the effect of a magnetic field on an ionized object, such as an oil droplet, regardless of the ability to detect a droplet with a single electron. Statistical methods should be sufficient to see the relevant patterns.

This report aims to use the result of an experiment called “Millikans Oil Drop Experiment” In which ionized droplets of oil are moved through a viscous air, to determine the force, and hence charge, on each droplet. The charge on an electron should be determinable by balancing the force due to the electric field with the force due to viscosity of air, using this formula, described further in the report.

$$q = \frac{4}{3}\pi\rho g\left[\sqrt{\left(\frac{b}{2p}\right)^2 + \frac{9\eta v_f}{2g\rho}} - \frac{b}{2p}\right] \times \frac{(v_f + v_r)}{E v_f}$$

This reports hypothesis is that the charge on each oil droplet will be a integer multiple of some fundamental amount of charge, E.

Materials and Methods

Materials

This experiment included an apparatus designed for this experiment, called the *droplet viewing chamber*. This apparatus is designed to allow the undisturbed free-fall of oil droplets between two charged or uncharged plates, whilst also allowing viewing using a viewing scope, and exposure to an ionization source. Specialised equipment exists for this purpose.

In addition to that apparatus, the material required are

- Voltage supply
- Switch capable of reversing polarity, and disconnecting the voltage supply
- Multimeter
- Thermometer
- Barometer
- Graph for conversion between temperature and air viscosity
- Mass scale

- Focusing wire
- Oil
- Oil atomiser
- Viewing scope with reticle (engraved hairline displacement scale)

Method

PART 1

The chamber is wiped clean on the interior with a paper towel and the separation of the capacitor plates is measured and recorded by measuring the thickness of the spacer, on the surface which the capacitor plates will be resting (Careful not to measure any lips or grooves).

A focusing wire is inserted into the hole of the upper capacitor plate. The brightness of the light source is adjusted such that there is maximum contrast when viewed through the scope. The scope is adjusted such that the reticle and also the wire are both in focus. The droplet hole cover and lid are both replaced.

PART 2

The DC power supply is attached to the capacitor plates and adjusted to supply about 500 Volts. A multimeter is connected across the plates, and the true voltage potential is recorded.

The barometric pressure is recorded. The ambient temperature is recorded, and used with the suitable graph to estimate air viscosity. The density of the oil is recorded, and loaded into the atomiser.

PART 3

The capacitor plates are disconnected from the voltage source. A sheet of paper is held near the atomiser nozzle, which is pumped rapidly until oil is coming out properly (no air occlusion which cause inconsistent oil flow). The ionization source lever is moved to 'spray droplet' position, the atomiser is placed at the hole in the lid of the viewing chamber, and an observer views through the eyepiece. The atomiser is squeezed until a sufficient spray enters the viewing area, at which point the ionization source lever is turned to 'off'.

From the eyepiece, a drop is chosen which is falling at 0.2-0.5 mm per second, and the capacitor plates are charged to whatever voltage causes droplet to begin rising. If the droplet does not respond to the charge, a new droplet should be selected.

The droplet should be allowed to rise through a pre-determined distance, and the time it takes to do so is recorded, with the distance and direction of travel (up/down). The capacitor polarization is toggled and the time taken for the droplet to travel the same distance is recorded, along with the distance and direction, again. This process should be repeated 10-20 times. If the droplet stops reacting to the voltage, a new droplet should be selected, and the chamber re-ionized, or the viewing chamber wiped clean.

Part 3 should be repeated entirely again, for as many droplets as is required.

Results

GROUP DATASET RESULTS

The measurements obtained from part 1 of this experiment is presented below in Table 1

Table 1 Measurements of experimental conditions

Measurement	Recording	Error
Plate separation (metres)	7.86×10^{-3}	10^{-5}
Plate Voltage (Volts)	502.9	0.005
Temperature (Celsius)	22	0.5
Air Viscosity (Nsm^{-2})	1.832×10^{-5}	0.006
Barometric Pressure (millibar)	1008	0.5
Oil Density		

The electric field strength between the two capacitive plates is given by $E = \frac{V}{r} = \frac{502.9}{7.86 \times 10^{-3}} = 64.0 \times 10^3 \; NC^{-1}$ with an error given by $\Delta E = E\left(\frac{\Delta V}{V} + \frac{\Delta r}{r}\right) = 64.0 \times 10^3 \left(\frac{0.005}{502.9} + \frac{0.00001}{0.00786}\right) = 1.28 \; NC^{-1}$.

The value of electric field intensity, for all droplets of this experiment was E=64.0 × 10^3 ± 1.28 NC^{-1}.

The data gathered for droplet #1 is presented in Table 2, as an example of the full dataset, which is available in full in Appendix 1 Group dataset

Table 2 Collected data for droplet 1

Travel Distance: 0.002 ± 0.000025 m

Trial N	Time Fall (s)	Velocity (mm/sec)	Δ Velocity (mm/sec)	Time Rise (s)	Velocity (mm/sec)	Δ Velocity (mm/sec)
1	3.570	0.056	0.008	1.410	0.142	0.050
2	5.490	0.036	0.003	1.260	0.159	0.063
3	5.990	0.033	0.003	1.020	0.196	0.096
4	6.920	0.029	0.002	0.920	0.217	0.118
5	5.140	0.039	0.004	1.320	0.152	0.057
6	4.180	0.048	0.006	0.920	0.217	0.118
7	4.420	0.045	0.005	0.790	0.253	0.160
8	6.400	0.031	0.002	0.790	0.253	0.160
9	3.690	0.054	0.007	0.900	0.222	0.123
10	4.000	0.050	0.006	0.790	0.253	0.160
AVERAGE	4.980	0.042	0.005	1.012	0.206	0.111

From the equations provided in the experimental instructions the charge on a drop of oil can be calculated by:

Equation 1 Equation to find charge, as a function of fall and rise times.

$$q = \frac{4}{3}\pi\rho g\left[\sqrt{\left(\frac{b}{2p}\right)^2 + \frac{9\eta v_f}{2g\rho}} - \frac{b}{2p}\right] \times \frac{(v_f + v_r)}{E v_f}$$

Where:
q = charge carried by the droplet [C]
d = separation of the plates in the droplet viewing chamber [m]
ρ = density of oil [kg/m^3]
g = acceleration due to gravity [m/s^2]
η = viscosity of air [N.s/m^2]
b = constant -= 8.20 x 10^{-3} [Pa.m]
p = barometric pressure [Pa}
v_f = velocity of fall [m/s]
v_r = velocity of rise [m/s]
V = potential difference across the plates [V]

Using the average values for fall velocity and rising velocity for this droplet (v_f and v_r) values presented in Table 2, this equation is now solvable for each droplet.

The error on q can be calculated by the equation in Equation 2, below.

Equation 2 Error calculation on charge, q.

$$dQ = Q(1.5\frac{\Delta V_f}{V_f} + \frac{\Delta V_f + \Delta V_r}{\Delta V_f + V_r} + \frac{\Delta V_f}{V_f})$$

For which the relative error is given by $\frac{\Delta q}{q}$. This process was done for all droplets in the dataset. The data for droplet three shows a dramatic, change in behavior after its 12th change in direction. For reasons mentioned in the discussion of this report, that data is presented below as belonging to two different drops, number 3 and 4.

The results are presented below, in Table 3.

Table 3 Calculated charge on each droplet.

Droplet Number (n)	Charge (Coulombs)	Absolute Error	Relative error
1	-1.103×10^{-18}	-8.198E-19	0.743
2	-9.291×10^{-19}	-6.682E-19	0.719
3	-8.501E-19	-5.665E-19	0.666
4	-5.277×10^{-19}	-5.563E-19	1.054
5	-4.083×10^{-19}	-2.047E-19	0.501
6	-2.468×10^{-19}	-9.973E-20	0.404

Droplet number 6, being the smallest, was then treated as being the fundamental charge which the others were multiples of. The charge on each droplet, and the error of charge on each droplet, was divided by the charge on droplet 6, to give the table below.

Table 4 Charge and error as a multiple of the lowest charge

Droplet #	1	2	3	4	5	6
Multiple of charge	4.46986	3.764392	3.444285	2.138017	1.654449	1
error	3.321552	2.707543	2.295096	2.254125	0.829439	0.404083

The table above was used to create Figure 1, below.

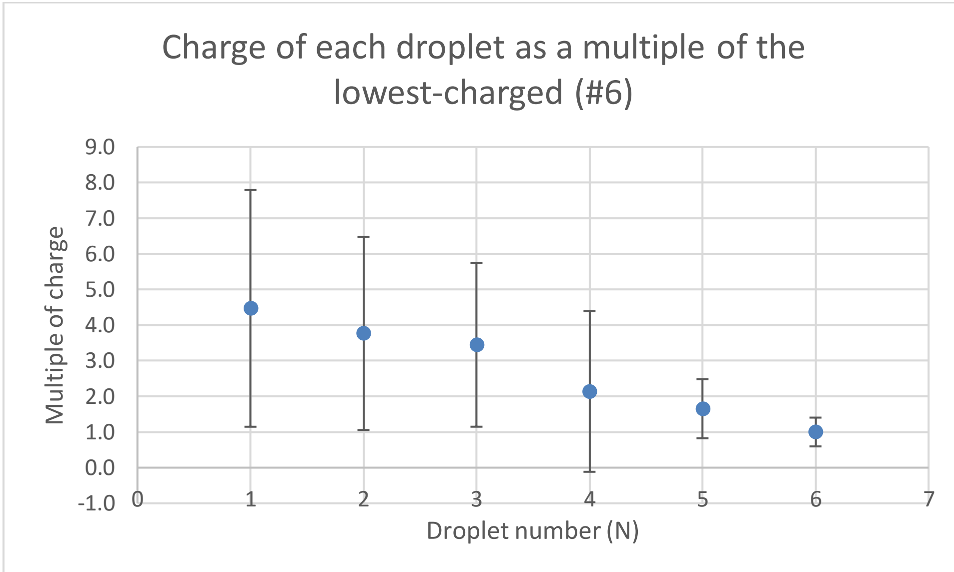

Figure 1 Charge as a multiple of the lowest charge

The same process was used as above, but comparing it to half of the lowest charge, to produce Table 5 Charge and error as a multiple of half the lowest chargeTable 5, below.

Table 5 Charge and error as a multiple of half the lowest charge

Droplet #	1	2	3	4	5	6
Multiple of charge	8.93972	7.528783	6.88857	4.276034	3.308897	1
error	6.643104	5.415085	4.590192	4.50825	1.658879	0.40408323

That data is presented in Figure 2 , presented below.

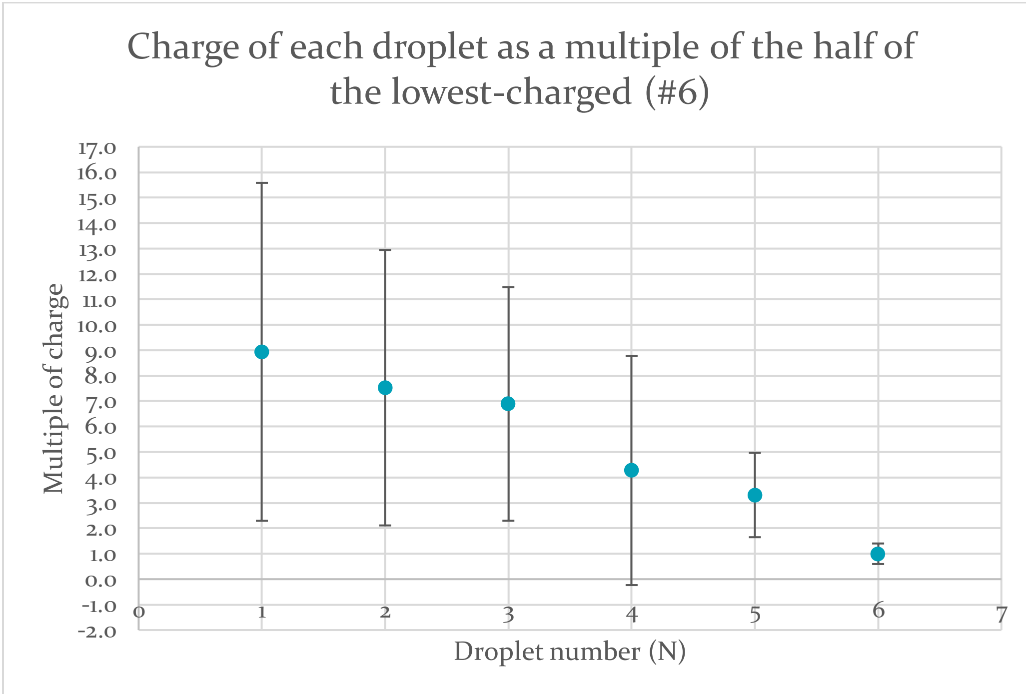

Figure 2 Charge as a multiple of the half of lowest charge

Figure 2 was further analysed by plotting how far from an integer multiple each droplet is. That data is presented below, in Figure 3

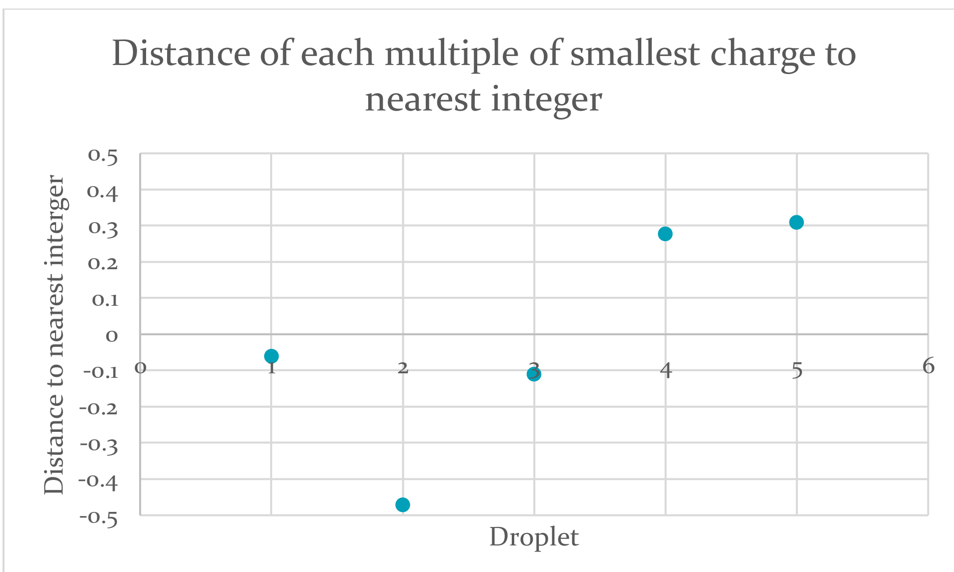

Figure 3 Each droplet's distance to an integer multiple

CLASS DATASET RESULTS

The class dataset was not performed under the same environmental test conditions (barometric pressure, temperature, etc), nor was the same voltage recorded across the capacitor plates, despite having the same intended voltage. Therefore, no single table can be given to show these conditions, however, that information is available in the full dataset, in Appendix 2 The full class dataset.

A sub-sample of the first 5 entries of the class dataset (N=182) is shown below in Table 6.

Table 6 Sub-sample of the class dataset

Trial N	vf (mm/sec)	Δvf (mm/sec)	vr (mm/sec)	Δvr (mm/sec)	d (mm)	T (˚C)	p [Pa]	V (Volt)
1	0.03863	0.01176	0.11325	0.03446	6.75	22.80	88900	500
2	0.07248	0.02206	0.27223	0.08284	6.75	22.80	88900	502
3	0.07174	0.02183	0.30102	0.09160	6.75	22.80	88900	499
4	0.03037	0.00924	0.81967	0.24943	6.75	22.80	88900	502
5	0.04864	0.01480	0.25907	0.07884	6.75	22.80	88900	502

The charge on the drops of oil was calculated from this data using Equation 1, and the error calculated using Equation 2, and a subset of the results are presented below in Table 7.

Table 7 Subset of the results of the class calculations of charge on each oil droplet

Droplet number (n)	Charge, q (Coulombs)	Δq (Coulombs)
1	-2.84×10^{-19}	-3×10^{-19}
2	-1.09×10^{-18}	-1.2×10^{-18}
3	-1.25×10^{-18}	-1.3×10^{-18}
4	-2.6×10^{-18}	-2.8×10^{-18}
5	-9.13×10^{-19}	-9.7×10^{-19}

The mean value of q was found to be $\bar{q} = 2.35 \times 10^{-19}$ with s standard deviation of $\sigma_q = 1.34 \times 10^{-16}$.

The class dataset was adapted such that all values were all positive, for reasons discussed in the discussion section of this report, and then sorted in order of their charge. There was an apparent discontinuity in the seven lowest values, and so data which was not within five orders of magnitude of the average was removed. This resulting data is presented below, on a log-linear graph (Logarithmic$_{10}$ Y-axis), in

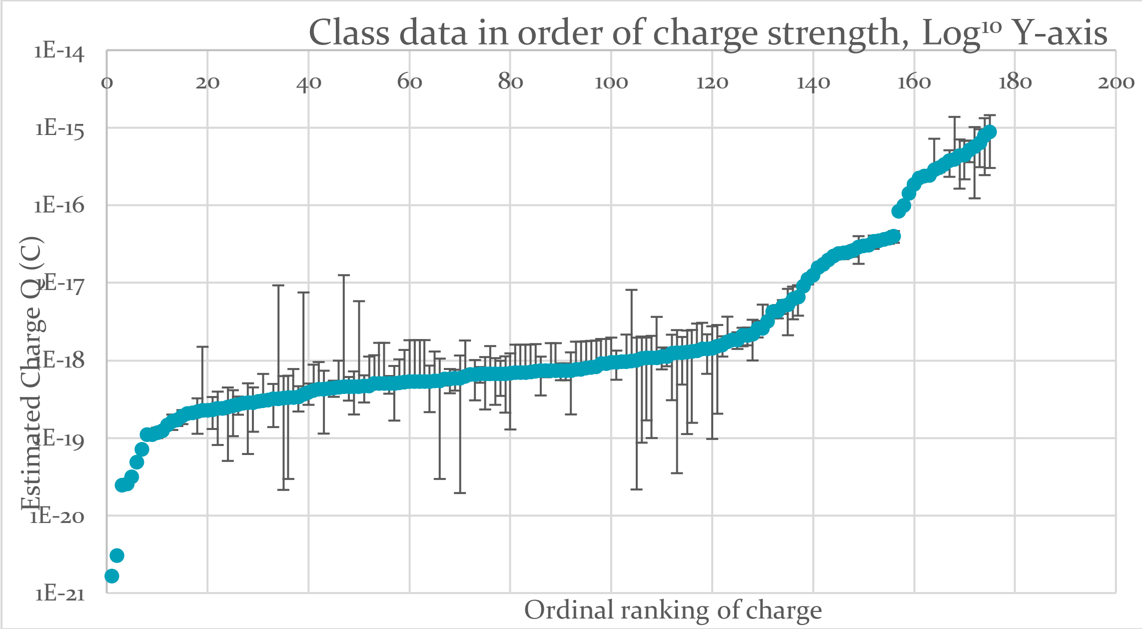

Figure 4 Class data sorted in order of charge, with estimated charge plotted on a log10 scale

The class data was arranged in ascending order of charge strength, and the difference between each sequential charge was found (a "step-difference"). The data was re-arranged in ascending order of those differences. From Figure 4 a data point was chosen as a 'guess' for the value of E, the fundamental charge. The point chosen was based on which one seemed to be part of the main sequence of data, but yet which was extremely small. This is because it could be assumed that a single-electron droplet may have been measured at least several time, and yet would be one of the smallest. The initial estimate was datapoint n=101, q=1.098×10^{-19} Coulombs, Because of the position on the graph. For each data point, the estimate of charge was divided by this guess, and rounded down to a whole number. The associated step-difference, calculated earlier, was then divided by this integer. The average of that ratio was then found; this process yields a second 'guess', an estimated value for E. It was found to be equal to E= 1.10×10^{-19} Coulombs, with a standard deviation of 8.349×10^{-21}.

Discussion

GROUP DATASET DISCUSSION

On the assumption that the charge on any given object is an integer multiple of some fundamental charge, and on the assumption that the amount of charge on the oil droplets is within a reasonable order of magnitude of that fundamental charge, the charge on each oil droplet was divided by the charge of the *least charged* oil droplet. The expectation is that the charges on the oil droplets would increase in steps of the size of some integer fraction of each other, or the least-charged droplet.

Figure 1 and Figure 2 show the results of this operation, and there is some apparent stratification involved, especially in Figure 2. This does not appear to hold up, as seen in Figure 3, where the data apparently has no tendency to be near an integer multiple, or any apparent trend as it approaches an integer multiple.

Group dataset error discussion

Droplet Three showed a strong change in its rise and fall times which was strong and consistent, and so not suspected to be a random error. It was concluded that this droplet had in fact been struck by another droplet of unknown size or charge. In the sense of this experiment, the droplet had become a new droplet, and so that data is treated as such in this report. The new droplet was named 'droplet 4'.

In Table 3 Calculated charge on each droplet., the relative error on the calculation for q is quite significant, with error margins of between 40% and 110%, and these errors perpetuate and are revealed in Figure 1 Charge as a multiple of the lowest charge, when it is seen that the error of margin for every droplet includes the error of margin for the least-charged droplet. The implication is that all of these droplets could in fact be equally charged, and there is no clear evidence that the rank order they are presented in is in fact the true order.

CLASS DATASET DISCUSSION

The class dataset was manipulated to have entirely positive values, because the experiment was performed in such a way as to disregard which sign (+/-) of charged plate the oil droplet was approaching in each measurement. This means that oil droplets of positive and negative charge are treated the same in the data, and there is in physics the general acceptance that an electron is equal and oppositely charged to a proton. Therefore, whether the ionization dislodged or added an electron is an immaterial difference, for this experiment.

The results of this experiment for the class dataset indicate an electron with a charge of E= 1.10×10^{-19} Coulombs, with a standard deviation of 8.349×10^{-21} Coulombs.This value is comparable in magnitude to the accepted value of $1.60217662 \times 10^{-19.}$ The standard deviation does not include the accepted value. This experiment comes close to the true value of charge of an electron, to within 0.4×10^{-19} Coulombs. This represents a relative error from the true value of 69%.

Class dataset error discussion

The data was gathered by a large collection of people in several dozen groups. The level of care taken in recording data is unknown, and may be reflected in some of the values in the dataset.

There are random errors involved in this experiment to do with the method of data gathering. The process of timing a droplet through a scope, crossing a hairline of comparable size to the droplet is a major source of error, perhaps the largest. A second source of error is the possibility that certain groups have mistaken their data, submitted it, and not being able to recognize their mistake. When this data is analyzed, it can be hard to determine which is mistaken, although the original creators may have been able to identify it as such.

Conclusions

This experiment was not able to confirm the accepted value for the charge on an electron, to within experimental error. This experiment had a large dataset, but was also plagued by that dataset coming from many different people, with attendant unknown errors.

Further experimentation, with a better controlled experimental environment and a review of the employed data analysis techniques may be necessary.

Appendix

Appendix 1 Group dataset

Droplet 1							
Trial N	Time Fall (s)	vf (mm/sec)	Dvf (mm/sec)	Time Rise (s)	vr (mm/sec)	Dvr (mm/sec)	d(mm)
1	3.57	0.056022409	0.007846276	1.41	0.141843972	0.050299281	7.86
2	5.49	0.036429872	0.003317839	1.26	0.158730159	0.062988158	7.86
3	5.99	0.033388982	0.00278706	1.02	0.196078431	0.096116878	7.86
4	6.92	0.028901734	0.002088276	0.92	0.217391304	0.118147448	7.86
5	5.14	0.038910506	0.003785069	1.32	0.151515152	0.057392103	7.86
6	4.18	0.04784689	0.005723312	0.92	0.217391304	0.118147448	7.86
7	4.42	0.045248869	0.00511865	0.79	0.253164557	0.160230732	7.86
8	6.4	0.03125	0.002441406	0.79	0.253164557	0.160230732	7.86
9	3.69	0.054200542	0.007344247	0.9	0.222222222	0.12345679	7.86
10	4	0.05	0.00625	0.79	0.253164557	0.160230732	7.86
AVERAGE	4.98	0.04221998	0.004670213	1.012	0.206466622	0.11072403	7.86
Droplet 2							
Trial N	Time Fall (s)	vf (mm/sec)	Dvf (mm/sec)	Time Rise (S)	vr (mm/sec)	Dvr (mm/sec)	d(mm)
1	2.83	0.070671378	0.012486109	2	0.1	0.025	7.86
2	3.14	0.063694268	0.010142399	1.88	0.106382979	0.028293345	7.86
3	3.05	0.06557377	0.010749798	1.17	0.170940171	0.073051355	7.86
4	2.39	0.083682008	0.017506696	2.38	0.084033613	0.01765412	7.86
5	3.31	0.060422961	0.009127335	1.36	0.147058824	0.054065744	7.86
6	3.15	0.063492063	0.010078105	1.71	0.116959064	0.034198557	7.86
7	3.62	0.055248619	0.007631025	1.5	0.133333333	0.044444444	7.86
8	3.54	0.056497175	0.007979827	1.71	0.116959064	0.034198557	7.86
9	3.02	0.066225166	0.010964431	2.18	0.091743119	0.021042	7.86
10	3.49	0.05730659	0.008210113	1.71	0.116959064	0.034198557	7.86
11	3.43	0.058309038	0.00849986	1.63	0.122699387	0.037637849	7.86
12	3.22	0.062111801	0.00964469	1.55	0.129032258	0.041623309	7.86
13	3.51	0.056980057	0.008116817	1.86	0.107526882	0.028905076	7.86
14	3.23	0.061919505	0.009585063	1.56	0.128205128	0.041091387	7.86
15	3.05	0.06557377	0.010749798	1.65	0.121212121	0.036730946	7.86
16	2.53	0.079051383	0.015622803	1.66	0.120481928	0.036289737	7.86
AVERAGE	3.156875	0.064172472	0.010443429	1.719375	0.119595433	0.036776561	7.86
Droplet 3							

Trial N	Time Fall (s)	vf (mm/sec)	Δvf (mm/sec)	Time Rise (s)	vr (mm/sec)	Δvr (mm/sec)	d(mm)
1	5.18	0.039	0.004	1.010	0.198	0.098	7.86
2	5.37	0.037	0.003	1.210	0.165	0.068	7.86
3	5.09	0.039	0.004	0.620	0.323	0.260	7.86
4	4.86	0.041	0.004	0.970	0.206	0.106	7.86
5	6.45	0.031	0.002	0.990	0.202	0.102	7.86
6	4.78	0.042	0.004	0.920	0.217	0.118	7.86
7	6.13	0.033	0.003	1.100	0.182	0.083	7.86
8	6.48	0.031	0.002	0.990	0.202	0.102	7.86
9	5.93	0.034	0.003	1.150	0.174	0.076	7.86
10	4.76	0.042	0.004	0.970	0.206	0.106	7.86
11	4.20	0.048	0.006	0.830	0.241	0.145	7.86
12	5.94	0.034	0.003	0.910	0.220	0.121	7.86
AVERAGE	5.430833333	0.037472589	0.003572638	0.9725	0.211347321	0.11545197	7.86
Droplet 4							
Trial N	Time Fall (s)	vf (mm/sec)	Δvf (mm/sec)	Time Rise (s)	vr (mm/sec)	Δvr (mm/sec)	d(mm)
13	4.00	0.050	0.006	1.620	0.123	0.038	7.86
14	5.00	0.040	0.004	1.780	0.112	0.032	7.86
15	4.03	0.050	0.006	2.460	0.081	0.017	7.86
16	4.60	0.043	0.005	2.770	0.072	0.013	7.86
AVERAGE	4.34	0.047	0.005	1.953	0.106	0.029	7.86
Droplet 5							
Trial N	Time Fall (s)	vf (mm/sec)	Δvf (mm/sec)	Time Rise (s)	vr (mm/sec)	Δvr (mm/sec)	d(mm)
1	5.77	0.035	0.003	1.740	0.115	0.033	7.86
2	6.27	0.032	0.003	1.940	0.103	0.027	7.86
3	7.09	0.028	0.002	2.150	0.093	0.022	7.86
4	6.31	0.032	0.003	2.240	0.089	0.020	7.86
5	7.12	0.028	0.002	2.170	0.092	0.021	7.86
6	6.59	0.030	0.002	2.010	0.100	0.025	7.86
7	6.13	0.033	0.003	2.340	0.085	0.018	7.86
8	5.65	0.035	0.003	1.870	0.107	0.029	7.86
9	7.43	0.027	0.002	1.860	0.108	0.029	7.86
10	7.51	0.027	0.002	2.330	0.086	0.018	7.86
11	5.95	0.034	0.003	2.190	0.091	0.021	7.86
12	5.99	0.033	0.003	2.030	0.099	0.024	7.86
13	5.71	0.035	0.003	1.830	0.109	0.030	7.86
14	6.47	0.031	0.002	2.140	0.093	0.022	7.86

15	6.21	0.032	0.003	2.200	0.091	0.021	7.86
16	5.77	0.035	0.003	2.250	0.089	0.020	7.86
17	7.21	0.028	0.002	2.090	0.096	0.023	7.86
AVG	6.42	0.031	0.002	2.081	0.097	0.024	7.86
Droplet 6							
Trial N	**Time Fall (s)**	**vf (mm/sec)**	Δvf (mm/sec)	**Time Rise (s)**	**vr (mm/sec)**	Δvr (mm/sec)	**d(mm)**
1	15.90	0.013	0.000	1.400	0.143	0.051	7.86
2	14.68	0.014	0.000	0.840	0.238	0.142	7.86
3	10.03	0.020	0.001	0.770	0.260	0.169	7.86
4	13.74	0.015	0.001	0.510	0.392	0.384	7.86
5	11.19	0.018	0.001	0.570	0.351	0.308	7.86
6	15.79	0.013	0.000	0.860	0.233	0.135	7.86
7	11.35	0.018	0.001	0.800	0.250	0.156	7.86
8	13.94	0.014	0.001	0.800	0.250	0.156	7.86
9	18.42	0.011	0.000	0.700	0.286	0.204	7.86
10	13.71	0.015	0.001	0.460	0.435	0.473	7.86
11	2.00	0.100	0.025	0.520	0.385	0.370	7.86
AVG	12.80	0.023	0.003	0.748	0.293	0.232	7.86

Appendix 2 The full class dataset

DROPLET N	vf (mm/sec)	Δvf (mm/sec)	vr (mm/sec)	Δvr (mm/sec)	d(mm)	T (˚C)	p [Pa]	V (Volt)
1	0.03863	0.01176	0.11325	0.03446	6.75	22.80	88900	500
2	0.07248	0.02206	0.27223	0.08284	6.75	22.80	88900	502
3	0.07174	0.02183	0.30102	0.09160	6.75	22.80	88900	499
4	0.03037	0.00924	0.81967	0.24943	6.75	22.80	88900	502
5	0.04864	0.01480	0.25907	0.07884	6.75	22.80	88900	502
6	0.54120	0.87618	10.92001	2.72325	9.10	22.90	101000	500
7	1.21960	1.97447	20.34292	5.07316	9.10	22.90	101000	500
8	0.27544	0.44592	28.70264	7.15792	9.10	22.90	101000	500
9	3.73261	6.04292	2.30542	0.57493	9.10	22.90	101000	500
10	0.04127	0.01250	0.10305	0.01331	9.00	22.80	101100	500
11	0.06425	0.01365	0.24178	0.01104	9.00	22.80	101100	500
12	0.08228	0.01317	0.17947	0.01389	9.00	22.80	101100	500
13	0.18437	0.01629	0.15645	0.01236	9.00	22.80	101100	500
14	0.10500	0.01325	0.15281	0.01138	9.00	22.80	101100	500
15	0.11754	0.01357	0.12494	0.00991	9.00	22.80	101100	500
16	0.22104	0.01285	0.12189	0.01241	9.00	22.80	101100	500

17	0.11666	0.01051	0.14045	0.01186	9.00	22.80	101100	500
18	0.11671	0.01171	0.17253	0.01055	9.00	22.80	101100	500
19	0.12315	0.01019	0.16995	0.01086	9.00	22.80	101100	500
20	0.03700	0.16000	0.13200	0.13600	8.00	23.00	91900	495
21	0.04200	0.01900	0.24100	0.41600	8.00	23.00	91900	495
22	0.27675	0.05933	0.15773	0.04009	7.68	22.90	91000	500
23	0.14809	0.03184	0.14270	0.02992	7.68	22.90	91000	507
24	0.06900	0.01449	0.14346	0.03001	7.68	22.90	91000	487
26	11.41000	0.00022	1.92000	0.00022	8.00	22.50	100700	490
27	11.18000	0.00039	2.59000	0.00022	8.00	22.50	100700	490
28	4.42500	0.00305	3.89000	0.00022	8.00	22.50	100700	490
29	4.59000	0.00305	2.14000	0.00022	8.00	22.50	100700	490
30	7.77500	0.00305	1.91000	0.00022	8.00	22.50	100700	490
31	7.98667	0.00305	1.24000	0.00022	8.00	22.50	100700	490
32	0.02000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
33	0.02000	0.01000	0.22000	0.01000	8.50	23.00	101000	498
34	0.01000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
35	0.02000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
36	0.02000	0.01000	0.25000	0.01000	8.50	23.00	101000	498
37	0.02000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
38	0.02000	0.01000	0.22000	0.01000	8.50	23.00	101000	498
39	0.02000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
40	0.02000	0.01000	0.22000	0.01000	8.50	23.00	101000	498
41	0.02000	0.01000	0.22000	0.01000	8.50	23.00	101000	498
42	0.02000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
43	0.02000	0.01000	0.22000	0.01000	8.50	23.00	101000	498
44	0.01000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
45	0.02000	0.01000	0.23000	0.01000	8.50	23.00	101000	498
46	0.01000	0.01000	0.22000	0.01000	8.50	23.00	101000	498
47	0.02000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
48	0.02000	0.01000	0.23000	0.01000	8.50	23.00	101000	498
49	0.02000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
50	0.01000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
51	0.01000	0.01000	0.24000	0.01000	8.50	23.00	101000	498
52	0.01000	0.01000	0.22000	0.01000	8.50	23.00	101000	498
53	0.07453	0.00252	0.19726	0.02211	7.74	23.00	100800	500
54	0.05325	0.00122	0.39906	0.01455	7.74	23.00	100800	500
55	0.09741	0.00100	0.12795	0.01604	7.74	23.00	100800	500
56	0.08578	0.00223	0.16364	0.00508	7.74	23.00	100800	500
57	0.00015	0.00003	0.00003	0.00001	7.54	21.00	1007	500

58	0.00012	0.00003	0.00002	0.00000	7.54	26.00	920	500
59	0.00033	0.00009	0.00001	0.00000	7.54	26.00	912	500
60	0.00060	0.00019	0.00001	0.00000	7.54	28.00	912	500
61	0.00101	0.00043	0.00001	0.00000	7.54	26.00	906	500
62	0.00010	0.00002	0.00021	0.00005	7.54	26.00	911	500
63	0.00013	0.00003	0.00004	0.00001	7.54	26.00	911	500
64	0.03863	0.01176	0.11325	0.03446	6.75	22.80	88900	500
65	0.07248	0.02206	0.27223	0.08284	6.75	22.80	88900	502
66	0.07174	0.02183	0.30102	0.09160	6.75	22.80	88900	499
67	0.03037	0.00924	0.81967	0.24943	6.75	22.80	88900	502
68	0.04864	0.01480	0.25907	0.07884	6.75	22.80	88900	502
69	0.01364	0.00684	0.11644	0.02356	7.95	23.50	91800	497
70	0.01401	0.00703	0.14313	0.02883	7.95	23.40	91600	497
71	0.01348	0.00676	0.19810	0.03989	7.95	23.30	91600	497
72	0.01788	0.00897	0.22124	0.04462	7.95	23.30	91600	497
73	0.01523	0.00764	0.32723	0.06594	7.95	23.20	91600	497
74	0.01257	0.00630	0.17253	0.03472	7.95	23.20	91600	497
75	0.02251	0.01131	0.36127	0.07307	7.95	23.20	91300	497
76	0.01315	0.00659	0.20408	0.04108	7.95	23.10	91300	497
77	0.01739	0.00872	0.19984	0.04032	7.95	23.10	91300	497
78	0.01489	0.00747	0.52854	0.10650	7.95	23.10	91300	497
79	0.05869	0.02969	0.36075	0.07427	7.95	23.10	91300	497
80	0.01225	0.00614	0.14384	0.02894	7.95	23.10	91200	497
81	0.01893	0.00950	0.39936	0.08063	7.95	23.00	91200	497
82	0.11400		0.75900		7.80	22.00	90600	500
83	1.56700		2.32400		7.80	23.00	90600	500
84	0.21600		0.78700		7.80	23.00	90600	500
85	0.20200		0.59300		7.80	23.00	90600	500
86	0.40500		1.96500		7.80	23.00	90600	500
87	0.66500		1.62800		7.80	23.00	90600	500
88	0.15700		0.49000		7.80	23.00	90600	500
89	0.45600		2.45600		7.80	23.00	90600	500
90	0.43000		1.78500		7.80	23.00	90600	500
91	0.59100		2.62900		7.80	23.00	90600	500
92	0.02621	0.00132	0.40078	0.08238	8.20	23.00	100000	505
93	0.03248	0.00184	0.20080	0.02502	8.20	22.70	100000	511
94	0.03128	0.00173	0.20441	0.02596	8.20	22.40	100000	511
95	0.04949	0.00365	0.39927	0.08864	8.20	22.50	100000	512
96	0.04005	0.00257	0.24690	0.03650	8.20	22.50	100000	512
97	0.04347	0.00294	0.16050	0.01680	8.20	22.60	100000	513

98	0.02345	0.00235	0.14011	0.01421	0.50	23.00	107000	499
99	0.03603	0.00362	0.14909	0.01533	0.50	23.10	107000	499
101	0.03365	0.00338	0.44301	0.04626	0.50	23.40	107000	500
102	0.02794	0.02794	0.04063	0.04063	0.50	23.30	107000	500
103	0.03365	0.02744	0.03987	0.03987	0.50	23.30	107000	500
104	0.01135	0.00227	0.11364	0.02299	7.76	23.00	101200	502
105	0.05139	0.01085	0.04669	0.01027	7.76	23.00	101200	502
106	0.02319	0.00561	0.06068	0.01451	7.76	23.00	101200	499
107	0.01737	0.00419	0.08532	0.01899	7.76	23.00	101200	500
108	0.01718	0.00477	0.37594	0.08616	7.76	23.00	101200	501
109	0.03237	0.23428	0.10883	0.48310	7.80	23.00	101000	503
110	0.02542	0.26945	0.10602	0.41908	7.80	23.00	101000	503
111	0.08319	0.22524	0.20377	0.31261	7.80	23.00	101000	503
112	0.02022	0.23050	0.14626	0.25290	7.80	23.00	101000	503
113	0.01258	0.00040	0.14286	0.05102	7.86	23.00	100700	504
114	0.01362	0.00046	0.23810	0.14172	7.86	23.00	100700	504
115	0.01994	0.00099	0.25974	0.16866	7.86	23.00	100700	504
116	0.01456	0.00053	0.39216	0.38447	7.86	23.00	100700	504
117	0.01787	0.00080	0.35088	0.30779	7.86	23.00	100700	504
118	0.01267	0.00040	0.23256	0.13521	7.86	23.00	100700	504
119	0.01762	0.00078	0.25000	0.15625	7.86	23.00	100700	504
120	0.01435	0.00051	0.25000	0.15625	7.86	23.00	100700	504
121	0.01086	0.00029	0.28571	0.20408	7.86	23.00	100700	504
122	0.01459	0.00053	0.43478	0.47259	7.86	23.00	100700	504
123	0.10000	0.02500	0.38462	0.36982	7.86	23.00	100700	504
124	0.01661	0.01291	0.21920	0.04908	7.54	23.00	101200	499
125	0.01705	0.00400	0.21587	0.10708	7.54	23.00	101200	499
126	0.01507	0.00392	0.22422	0.07556	7.54	23.00	101200	499
127	0.02461	0.00587	0.08728	0.03314	7.54	23.00	101200	499
128	0.01516	0.00403	0.10852	0.03146	7.54	23.00	101200	499
129	0.03998	0.00939	0.18823	0.04811	7.54	23.00	101200	499
130	0.01943	0.00489	0.07022	0.70885	7.54	23.00	101200	499
131	0.01787	0.00436	0.18570	0.09904	7.54	23.00	101200	499
132	0.01480	0.00764	0.20400	0.10531	7.54	23.00	101200	499
133	0.02882	0.01347	0.11761	0.05495	7.54	23.00	101200	502
134	0.01636	0.00083	0.09293	0.00508	7.76	23.20	100700	502
135	0.07733	0.00417	0.15821	0.00916	7.76	23.00	100700	503
136	0.03009	0.00155	0.11713	0.00654	7.76	23.00	100700	503
137	0.01750	0.00089	0.26184	0.01653	7.76	22.80	100700	503
138	0.00870	0.00088	0.23606	0.02930	7.76	22.70	100700	501

139	0.04494	0.00470	0.33857	0.04549	7.76	22.80	100700	503
140	0.02579	0.00265	0.17788	0.02096	7.76	22.80	100700	503
141	0.01830	0.00311	0.16595	0.03228	7.76	22.90	100700	503
142	0.05545	0.00585	0.34621	0.04703	7.76	23.00	100600	503
143	0.04866	0.00510	0.45930	0.06723	7.76	23.20	100600	503
144	0.00781	0.00100	0.16949	0.05998	7.70	22.00	101500	501
145	0.00910	0.00100	0.13824	0.05998	7.70	22.00	101500	501
146	0.00676	0.00100	0.41667	0.05998	7.70	22.00	101500	501
147	0.00893	0.00100	0.70423	0.05998	7.70	22.00	101500	501
148	0.06341	0.00740	0.17833	0.05998	7.70	22.00	101500	503
149	0.05387	0.00740	0.45002	0.05998	7.70	22.00	101500	503
150	0.03696	0.00740	0.28617	0.05998	7.70	22.00	101500	504
151	0.24000	0.00700	0.22000	0.00600	7.50	22.00	101400	490
152	0.14600	0.00700	0.11700	0.00500	7.50	20.00	101400	504
153	0.17700	0.00900	0.16500	0.00700	7.50	18.00	101500	509
154	0.18800	0.00900	0.17700	0.00700	7.50	18.00	101500	510
155	0.24700	0.00800	0.23300	0.01600	7.50	18.00	101500	510
156	3.09200	0.31920	5.51300	0.56130	7.00	23.00	101400	500
157	3.07300	0.23150	2.48400	0.25840	7.00	23.00	101400	500
158	3.00900	0.32570	2.73500	0.28350	7.00	23.00	101400	500
159	2.91600	0.17020	2.26000	0.23600	7.00	23.00	101400	500
160	2.83200	0.34210	3.75700	0.38570	7.00	23.00	101400	500
161	2.78200	0.33300	3.75400	0.38540	7.00	23.00	101400	500
162	2.64500	0.16980	1.85400	0.19540	7.00	23.00	101400	500
163	2.53800	0.14440	1.59200	0.16920	7.00	23.00	101400	500
164	2.40600	0.19860	2.15700	0.22570	7.00	23.00	101400	500
165	2.33100	0.14720	1.52000	0.16200	7.00	23.00	101400	500
166	2.21500	0.16910	1.75833	0.18583	7.00	23.00	101400	500
167	2.16100	0.16020	1.79100	0.18910	7.00	23.00	101400	500
168	2.12200	0.21590	2.30400	0.24040	7.00	23.00	101400	500
169	0.07439	0.01291	0.05398	0.00937	10.00	21.00	101500	500
170	0.03263	0.00339	0.21701	0.02253	10.00	21.00	101500	500
171	0.09918	0.01082	0.24656	0.02689	10.00	20.00	101500	504
172	0.05944	0.00621	0.74266	0.07762	10.00	20.00	101500	504
173	0.06476	0.00688	0.10611	0.01127	10.00	20.00	101500	502
174	0.07322	0.00760	0.58524	0.06076	10.00	20.00	101500	502
175	0.89000	0.50000	15.15000	0.50000	9.00	21.00	101960	507
176	1.96000	0.50000	6.45000	0.50000	9.00	21.00	101960	508
177	0.89000	0.50000	11.92000	0.50000	9.00	20.00	101960	509
178	2.66000	0.50000	8.72000	0.50000	9.00	22.00	101960	509

179	1.21000	0.50000	8.67000	0.50000	9.00	23.00	101960	509
180	1.41000	0.50000	11.06000	0.50000	9.00	22.00	101960	509
181	0.90000	0.50000	14.42000	0.50000	9.00	22.00	101960	509
182	1.09000	0.50000	19.87000	0.50000	9.00	22.00	101960	509
183	2.75000	0.50000	2.40000	0.50000	9.00	22.00	101960	503
184	1.48000	0.50000	8.34000	0.50000	9.00	22.00	101960	509